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THE CONSTRUCTION OF THE PENNSYLVANIA R. R. TUNNELS UNDER THE HUDSON RIVER AT NEW YORK CITY.*

By JAMES FORGIE,† M. Am. Soc. C. E., M. Inst. C. E.

II. Driving the Tunnels.

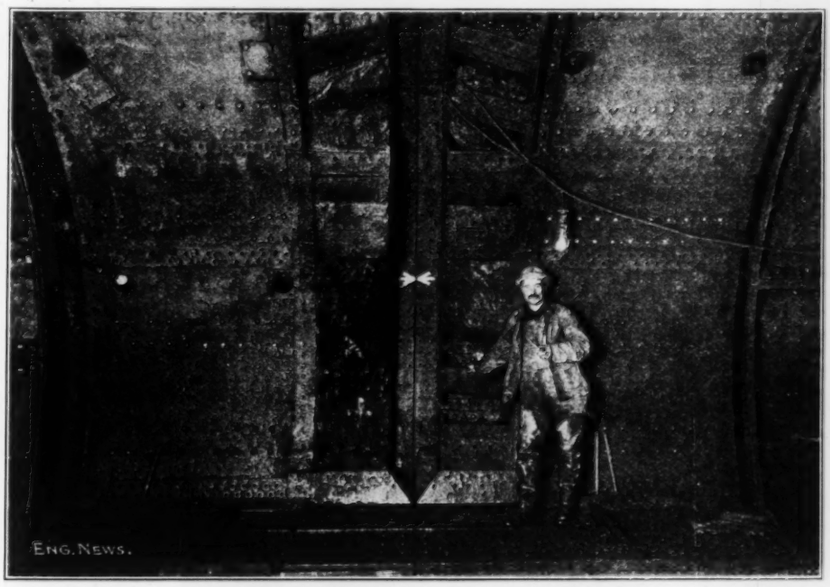
The plan for the construction of the Pennsylvania R. R. Hudson (North) River tunnels at New York City‡ contemplated the erection of shields and the inauguration of pneumatic working at a comparatively early date, owing to the early provision made in shaft sinking, design of shields and other preliminary work. The shield chambers were placed as completely as possible within solid rock, and the working shafts were located as near the shield chambers—or more properly as near the river—as was practicable, with a view to reducing the length between the shaft in New York and the shaft in New Jersey to a minimum. At Weehawken there were no obstacles to restrict the location, and the shield chambers were placed in solid rock. At Manhattan, however, the contract track plans would not permit of so simple a solution, compelling the location of the chambers in ground which was part rock and part sand and silt. Fortunately, however, these track plans were altered, and advantage was taken of this to locate the shield chambers 133 ft. to the landward (east) of the original position, enabling them to be constructed in practically full-face rock, with the exception, noted in the writer's earlier article, that a pocket in the surface of the rock at one point caused a troublesome cave-in. A similar accident interrupted the work at Weehawken, riverward of the shield chamber, while driving as far ahead of the shield chamber without compressed air as safe working in the rock would permit previous to installing the shield.

This Weehawken cave-in occurred in the north tunnel, Feb. 14, 1905, and produced a surface disturbance as exhibited in the view Fig. 26. The nature of the soil involved is strikingly characterized by the fact that a mass of ground flowed into the tunnel, filling it to almost half its height for a distance of about 300 ft. back of the face. Fig. 27, a view of the west or inshore end of this great muck flow, suggests the almost fluid behavior of the material in its irruption.

The two cases noted were the only serious interruptions to the work previous to the erection of the shields, apart from the usual difficulties encountered where little or no cover was found in full-face rock, landward of the shield chambers at the Manhattan end. The main interest of this article centers in the construction of the shield-driven or subaqueous tunnels.

The Shield-Driven Tunnels: Methods and Experiences.

The general working arrangements in the tunnel have already been given in the writer's first article, describing airlocks, working and bolting platforms, shield and accessory provisions. A diagram longitudinal section of the tunnel illustrating the combined arrangements is shown here as Fig. 28.



Shield from New York. Shield from New Jersey.

FIG. 25. JUNCTION OF SHIELDS, NORTH TUNNEL, PENNSYLVANIA R. R. HUDSON RIVER TUNNELS, NEW YORK CITY.

View looking at side of tunnel, in the plane of junction of the cutting-edges (vertical line in middle). The shields have been partly dismantled, in preparation for completing the lining. Note how corresponding rivet and joint lines and the platforms of the shields coincide.

With regard to the methods of working and the difficulties encountered in driving the shield tunnels, the operations may be classified according to the different sorts of ground passed through:

A. Shield all in rock.

B. Shield partly in rock, with water and soft ground above, the soft ground consisting of sand, gravel, boulders, etc.

C. Shield entirely in wet sand, gravel and boulders.

D. Shield in silt with piles, riprap, or other obstructions.

E. Shield in full silt face.

A. SHIELD IN FULL ROCK FACE.—Where this condition existed the rock was excavated as far as practicable to full section in advance of the shield. In the bottom was laid a cradle consisting either of one middle rail or three rails, one in the middle and one on each side and parallel with it about 4 ft. away. These rails were set to true line and grade of the tunnel and were concreted in. Fig. 29, a view in the rock heading forward of the shield, looking back toward the shield, shows the three rails set in position. The concrete invert, which was carried up the sides to about the axis level of the tunnel, formed a smooth, even bed on which the shield moved. Where the surface of the rock descended so that it was no longer possible to excavate the full section ahead of the shield, a bottom heading was kept from 15 to 20 ft. in advance of the shield, about 16 ft. wide by 10 ft. high; in the bottom of this also was laid a rail and concrete cradle, and up to the point where rock disappeared the shield traveled on a prepared surface.

No attempt will be made to describe in detail the operation of erecting the iron lining, as this may be easily gathered from the drawings accompanying this article, and is of course a comparatively simple operation. Like many other simple repetition operations in construction, it becomes an art with the practice obtained by doing it week after week and month after month, and a gang may be relied upon after say a month's experience, to diminish the time required in the erection of a ring to the extent of anywhere from one-half to one-fifth the time required at the outset. However, some particulars which are special to the several kinds of ground may be mentioned. It was found that through the rock, and even where it existed only from invert to axis level, the iron had the natural tendency to increase in horizontal diameter, as the excavation had to be made large enough for the shield to pass, thus leaving the iron shell without external abutment. Tie-rods, of 1½-in. diameter, with turnbuckles, were therefore freely used in the tunnel through the rock; they were kept tight and in place until the iron lining was grouted. These tie-rods ap-

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‡See the first half of this article, on Tunnel Design, Shields and Plant, in Engineering News of Dec. 13, 1906.

THE PATH OF THE PENNSYLVANIA R. R. HUDSON RIVER TUNNELS, LOOKING EASTERLY TOWARD NEW YORK CITY FROM WEEHAWKEN SHORE.

pear clearly in the photograph Fig. 18 of the writer's article on Tunnel Design, shields and plant of this undertaking. (Eng. News, Dec. 13, 1906.)

All voids left outside the tunnel lining were filled with Portland cement grout of 1 part cement to 1 of sand by volume. In the case of large holes these were packed with hard dry stone and afterward grouted. Packing with loose rock between the fast rock and the shield, apart from the concrete and rock cradle to axis level, was avoided where it was likely to work around the shield in the process of shoving, as this is liable to detrimentally affect the alinement of the shield and thereby of the completed tunnel. In full face rock it was the practice to put in 20 or 30 rings without grouting and then grout this length as a whole. For this purpose the shield was shoved until the tail was completely free of the last ring. A concrete stop eye-wall was then built around between this last ring and the rock, to retain the grout, which was put in under an air pressure of from 70 to 100 lbs. per sq. in. by means of the grouting machine.

B. FACE PARTLY ROCK WITH SOFT GROUND ABOVE.—This condition of ground involved poling and breasting the roof and face. The method normally adopted is shown in Fig. 30. The poling and breasting boards are of 2-in. lumber, the breasting boards set vertically and held by walings in turn caught by the sliding platforms of the shield. The top part of the face was frequently held by a stretcher or stretchers (poling struts) butting against a waling placed against the breasting, the struts being carried through the shield pockets and butting against cross timbers placed across the top part of the tunnel lining behind the shield and tightened by means of a screw jack permanently fixed on the rear end of the strut. Where it was considered unsafe to carry these struts through the shield doorways, steel pipe struts were used, passing through the holes of 3½-in. diameter provided in the front and rear diaphragms of the jack-pockets of the shields.

It should be noted, as it has been stated previously, that Fig. 30 illustrates a typical method of dealing with this class of face, and that generally the rock face and the poling were kept further in advance of the shield than shown. The sliding platforms were of great service in this class of face; notwithstanding they are comparatively delicate mechanical parts of the shield, and exposed more than other parts to blasting maltreatment, they continued intact throughout the entire work.

The writer's attention has been called to a recent case of a shield passing through rock, where the shield was greatly damaged and distorted. This was doubtless due more or less to inaccessibility of the face at the bottom, when chances would be taken as to whether the rock was entirely cleared beyond the outside of the shield, with the result that in some instances such would not be the case. It is interesting to note that these tunnels of the Pennsylvania R. R. are the first work with such a face where a concrete cradle was specifically required under the contract, and the desirability of such has been very much emphasized in recent tunnel operations of this character, with reference to stability of both the tunnel lining and shield. In such ground no chances can be taken in having the surrounding rock entirely clear of the shield, as with the immense power propelling the shield the strongest structure of the kind can be readily damaged to such an extent as to give great trouble in the erection of the iron, or be made entirely useless. The same trouble may be similarly experienced with boulders in gravel.

C. FACE ENTIRELY OF WET SAND, GRAVEL AND BOULDERS.—There were two general arrangements of timbering used in this sort of ground. An attempt was made at the outset to use vertical breastboards held by walings in a somewhat similar way to that described in the last type of ground, but it proved a failure. The other method, which was adopted, consisted of horizontal breastboards held by upright pieces or "soldiers" in turn held by walings, these being held by struts passing through the holes in jack-chamber diaphgrams or the pockets as described before and by the sliding platforms on the front of the shield. It is perhaps unnecessary to state that in advancing a vertical breastboard it opens a face with a much greater difference in pressure between top and bottom than in the case of a horizontal breastboard, but it sometimes happens that a ground with the aid of air-pressure will permit of this treatment; in this case, however, it was impracticable. Both arrangements are sketched in Fig. 31. It was also impracticable to use horizontal breastboards in the part of the face below the lower platforms, where it was very wet, and here vertical sheet piling was adopted; one row of piling is shown, but it was sometimes necessary to use two rows, where the ground was exceptionally wet and the sand flowed like water.

It was originally arranged that in this sort of ground the timbering would not be advanced more than 15 ins. or half a ring length at a time and the hood of the shield was therefore designed and constructed with this end in view. Had this plan been adhered to, and had the method of scooping out the sand or gravel ahead of the periphery of the hood and replacing the same with clay pug been adopted, the sequence of operations in setting forward the face would have been as shown and described in Fig. 32, and roof poling would have been obviated [also, of course, owing to the inability to hold the ground with air-pressure below the bottom platform, the vertical poling as used would neces-

FIG. 26. SURFACE CAVE-IN IN ERIE R. R. FREIGHT YARDS, WEEHAWKEN, N. J., CAUSED BY INFLOW OF SOFT GROUND INTO TUNNEL BELOW. FEB 14, 1905.

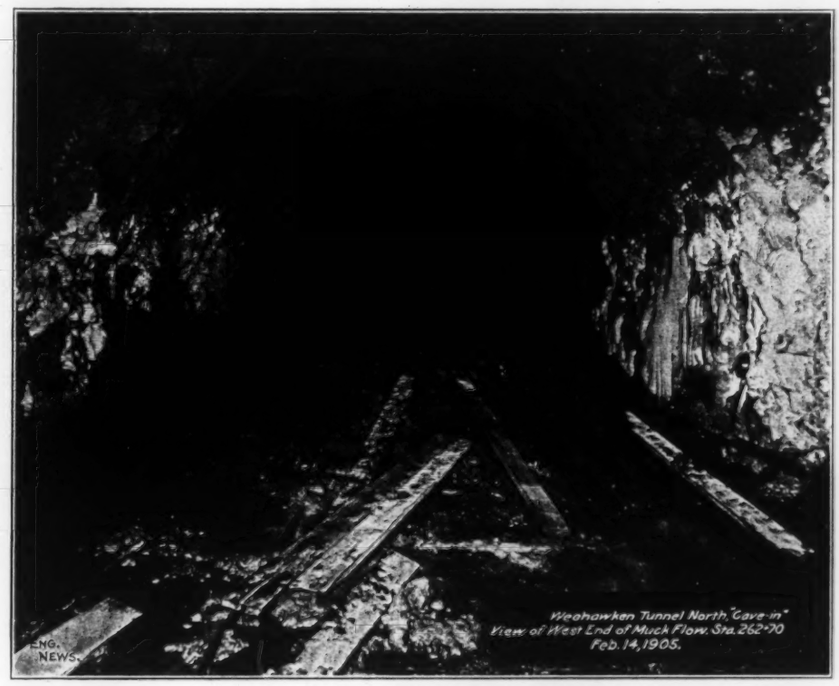


FIG. 27. VIEW OF WEST END OF MUCK FLOW IN WEEHAWKEN HEADING OF NORTH TUNNEL; CAVE-IN UNDER ERIE R. R. FREIGHT YARDS.

sarily have displaced the horizontal poling, as shown on this figure]. In actual work, however, the length of shove was not restricted to a half ring length, and it was therefore necessary to pole the roof over and ahead of the hood. The rest of the operation was similar to that shown in Fig. 32, except that the poling struts shown on that drawing were not used, and as a rule pieces of steel tube passing through the holes provided for the poling struts were used.

Where there was considerable escape of air the joints in the poling and breasting were stopped with puddled clay and the face grouted under pressure through holes bored in the breast boarding. Salt hay and small bags of sawdust were freely used to choke air blows during the process of setting forward the polings. The method shown in the drawing of forming an annular chamber filled with puddled clay round the forward end of the hood prior to shoving, the chamber being taken out in small pockets one at a time, was, as already noted, not adopted in the ground encountered, though it had been found of great value on work in the charge of its deviser, Mr. H. H. Dalrymple-Hay, in tunnels driven through water-bearing gravels under the River Thames at London, England, and since then in tunnels driven in similar ground.

In ground of this description the grouting is of the greatest importance in maintaining the stability of the surrounding material. It was carried on continuously and kept as near up to the last erected ring as was possible, with due regard to avoiding trouble by grouting the tail of the shield to either the iron erected or the surrounding material. From observation in this class of face with tunnel operations where the hood extended two-thirds, and in the present case where it extended only down about one-third of the depth of the shield, the writer has formed the opinion that the former is preferable.

Owing to the impossibility on the New Jersey side of holding back the water at the face in sand and gravel, notwithstanding the aid of compressed air, much difficulty and delay resulted from the inflow of water. Finally, however, the expedient of letting one tunnel serve as drain to its neighbor was resorted to, and thereby the difficulties with water were much reduced. Under this plan the north and the south heading were advanced alternately. When one shield was some distance ahead of the other, it was stopped and the air-pressure behind it reduced, while pumping was continued. This idle heading then acted to draw down the ground-water sufficiently to reduce the inflow at the face of the other heading, and work on the latter was resumed until it had been pushed ahead of the shield last advanced. While this was slower than if both headings had been kept advancing, it proved very useful in minimizing the trouble and risk of the work. The air-compressors were here taxed to their full capacity for over two months without once failing. Owing to the difficulty of holding the air there were the inevitable difficulties and troubles at the surface in the railroad yards of the New York Central in New York and the Erie Railroad in New Jersey; apart from these and a run which resulted in the loss of a man in the sand at the face, the work was expeditiously and successfully carried out.

D. FACE OBSTRUCTED BY PILES, OR PILES AND RIPRAP, OR BOTH.—When an obstruction consisting solely of groups of piles was encountered, no timbering at all was done, the hood carrying the roof ground and the piles in the face serving as face supports. The piles were cut out by axes in pieces suitable for handling through the shield. Where riprap was present, it was sometimes necessary to roughly pole the roof, but no extensive timbering was done.

In passing under the river bulkhead wall on the Manhattan side a considerable escape of air occurred around and even at the bottom of the tail of the shield (Fig. 33), which at one time removed the cover of silt above the tunnel, leaving the iron lining exposed to the river with 60 ft. of water overlying. The water-blows in the river would occasionally rise over 20 ft. above the normal surface of the river. On clearing the riprap to the west or riverwards of the bulkhead wall it took some time to get rid of the influence of having so much of the river-bed blown away, and heavy blows continued until about 300 ft. from the river bulkhead. This blowing was finally stopped by placing about 16,000 cement sacks filled with silt over each tunnel. The location made it impossible to dump this en masse from a scow. While it lasted, this work in both tunnels fully taxed the entire capacity of the compressor plant, including the high-pressure air compressor, for over two months.

In passing through riprap, sufficient grouting outside the tunnel was done to form a protecting covering to the lining.

E. FULL FACE SILT.—It was generally supposed that when the shields got fairly under the river and into the soft silt of the Hudson the shield doors would be shut and the tunnel building carried on without removing any excavation as had been done with the South Tunnel of the N. Y. & J. Ry. one of the tunnels at Morton St., New York. However, it soon became evident on trying this that such a method in the case of these larger tunnels was impracticable, as the shield tended to rise and this carried the tunnel upward and made it impossible to keep to the required grade even with a large downward inclination on both iron and shield. This made it necessary to take in a certain proportion of the excavation, which proportion has varied from 20% to 100% of the shield displacement, throughout the length under the river. This amount of muck could generally be got by opening wholly or partly the bottom middle door of the shield. The work is typically illustrated by the photograph reproduced in Fig. 34.

No grouting was done in full silt, except under exceptional circumstances, such as under the heavy structure of the cold-storage warehouse adjoining the river-front on the Weehawken side, where it was deemed advisable in carrying this

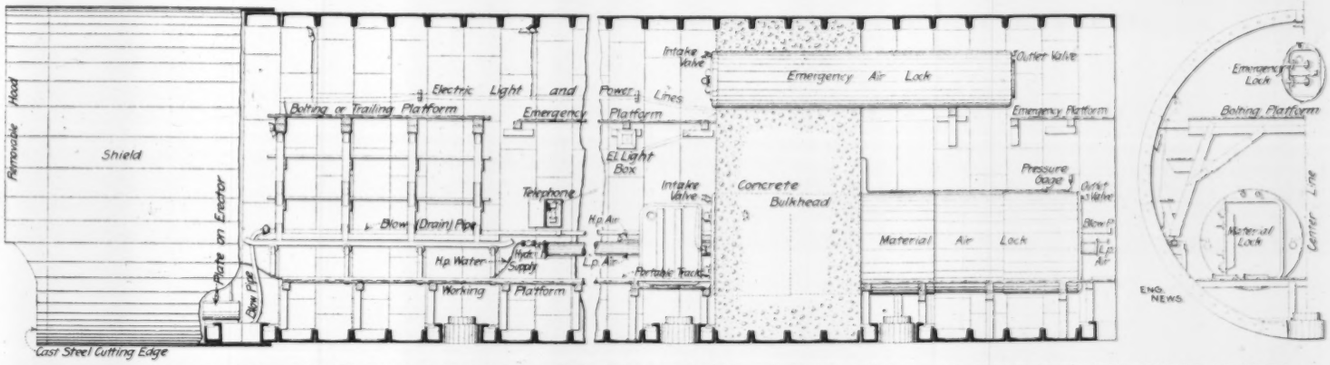


FIG. 28. DIAGRAMMATIC LONGITUDINAL SECTION OF TUNNEL, SHOWING ACTUAL WORKING ARRANGEMENTS FOR SHIELD DRIVING (SUBAQUEOUS TUNNELS).

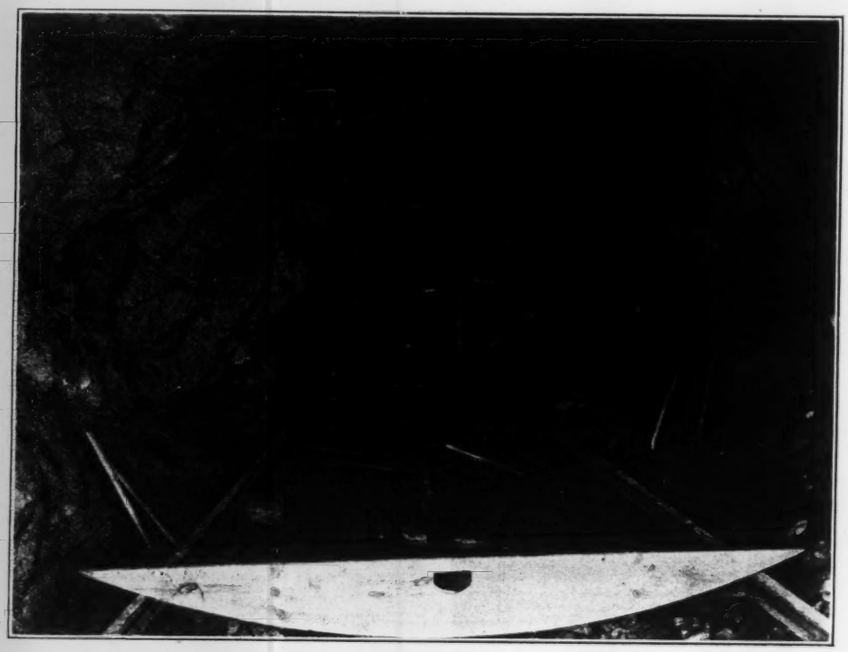


FIG. 29. VIEW AHEAD OF SHIELD IN ROCK, LOOKNG TOWARD FRONT OF SHIELD; INVERT RAILS FOR CONCRETE CRADLE IN PLACE.

structure on piles resting directly on the tunnel, to make up for the volume displaced by the tail of the shield. [Further, in such locations, where structures are involved and any doubt is entertained as to the stability of the tunnel owing to such local conditions, it is intended to incorporate in the concrete lining within the cast-iron shell steel-bar reënforcements.]

GUIDANCE OF SHIELDS.

It may be of some interest to note in this connection the various difficulties which confront the undertaking of driving a tunnel through the kinds of ground met with on this work, in such a way that the contemplated line and grade may be obtained.

In the first place, the cross-sectional area of the tunnel is reduced for motives of economy to the smallest possible area and this, of course, reduces the permissible deviation both vertically and horizontally from the true line and grade to a small dimension. In the second place the character of the ground in most cases tends to make it difficult either to maintain true grade or to maintain a good shape, that is to say, a perfectly circular cross-section of the tunnel. The maintenance of the alinement does not prove such a difficult matter as maintenance of true grade.

The way to ensure the maintenance of true grade, line and shape is undoubtedly frequent "checking," that is to say, to have the actual position of the tunnel lining and shield, with reference to theoretical position, verified at frequent intervals, and to act as frequently as may be indicated thereby. At an early stage of the work it was decided that these checks should be made on every fourth ring (that is, every 10 ft.) throughout the tunnel, and this decision has been adhered to, except where unwonted difficulty in keeping true line or grade has arisen, in which case checks were taken on every second ring. This necessitated a large alinement staff, as the work had to be carried on both by day and by night, as well as a large inspecting staff to see that the instructions which followed as a result of the checking of the tunnel were properly carried out. This, with the ready and cheerful cooperation of the contractor's officials in following instructions, has resulted in a piece of tunnel work of high excellence both in closeness to line and grade and in general workmanship. The large amount of what was called "precise record work," that is to say, constant rerunning of lines and grades and measurements to determine the shape of the tunnels throughout their entire length, all made necessary by the unstable

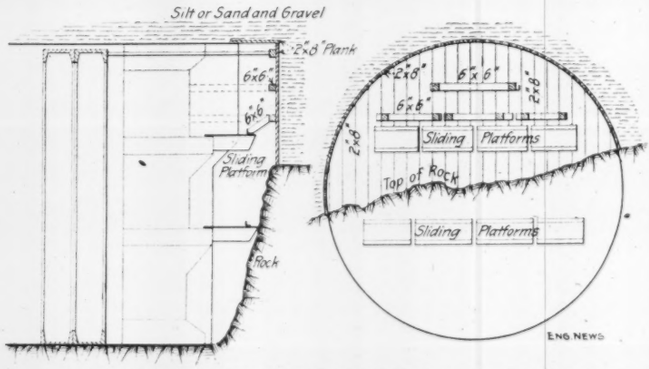


FIG. 30. METHOD OF TIMBERING THE BREAST IN PART-ROCK FACE.

nature of the silt in which the sub-river part of the work is constructed, has resulted in more information being collected in connection with these tunnels than has probably been collected for any similar piece of work since shield-tunneling was developed. The precision with which the shields met, illustrated in the case of the north tunnel in the view on the first page, Fig. 25, is partial testimony to the quality of the work done both by the Engineer's corps and the Contractor's forces.

In describing the guidance of the shields, it may be convenient to divide the work into classes, corresponding to the different sorts of ground passed through, as was done when describing the operation of excavating.

A, B. TUNNEL IN ROCK.—As described above, a cradle was laid on the bottom, on which the shield slid. This cradle was at first set so that the tops of the embedded rails were at the level of the outside invert of the tunnel. Then as the shield passed along the cradle the iron erected within it was high by the amount of the thickness of the shield skin (2⅛ ins.); when the shield was moved ahead, the iron lining behind settled down on the cradle so that it was at true grade. The difficulty experienced was in keeping line. As the cradle has to be made large enough to take the shield, there was necessarily a certain amount of play at the axis level outside of the lining, so that the iron did not always come down vertically on the cradle. However, by dint of wedging outside the shield, the iron at this part of the tunnels has been kept within 0.20 ft. of the true center line.

When the point at which the rock disappeared below the tunnel invert was approached and it became necessary to grout continuously instead of in lengths at a time, the cradle rail was brought down so that it coincided with the grade of the shield skin, i. e., 2⅛ ins. below the tunnel invert. Then as grouting was continuous, the iron was held from settlement by the grout beneath it.

C. TUNNEL IN GRAVEL, SAND, ETC.—Hitherto the tunnel has had a firm foundation on which to rest; from now on during construction, however, the foundation is more or less unstable, and there is no possibility of providing any guide on which the shield may travel. Dependence therefore has to be placed on the shield itself as a dirigible machine for maintaining grade and level. In order to describe the method of directing a shield it will be necessary to go back to a few first principles of shield driving to explain the terms used hereafter.

First, if the tunnel were being driven through a perfectly unyielding substance as hard clay, it might be supposed that the plane of the face of the leading ring could be kept square to the axis, and with the axis of the tunnel coinciding with the theoretical axis, and that if such a state of affairs were once inaugurated, there would be no tendency for the tunnel to deviate at all from its true position. However, in soft ground, the weight of the shield and lining tends to disturb this ideal state of affairs so that recourse has to be had to means for counteracting the tendency of the work to deviate from true position.

This is chiefly arrived at by means of "leads." The lead is the amount by which the plane of the front of a ring of lining or the front of the shield is off square with the true or required axis of the tunnel; lead is therefore of two kinds, namely, vertical and horizontal. The two sketches given in Fig. 35 show in an exaggerated way the meaning. Thus in the upper sketch the iron has a lead of a in the bottom, while the shield has a lead of b over the iron at the bottom or a total lead of $a + b$ in the bottom. The second sketch shows the iron lining with a lead of a on the south, while the shield has a lead on the north of $a + b$

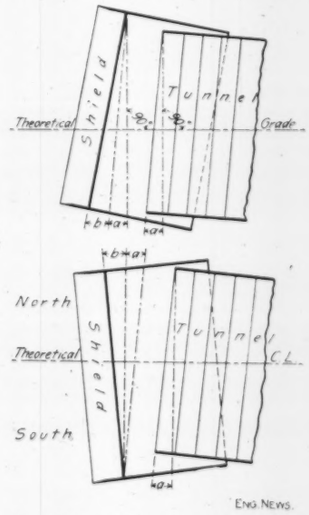


Fig. 35. Diagram Illustrating Leads of Lining and Shield.

over the iron, or a lead of *b* on the north from the true square line.

It is usual to express the lead of the iron in terms of deviation from the true square line, both at sides and at the top and bottom, while the lead of the shield is expressed in terms of its deviation from the last ring of iron erected. Thus the last ring may have a lead of 2 ins. in the top and the shield still further by ½-in. in the top, in which case the lead of the iron would be a top lead of 2 ins., and that of the shield a top lead of ½-in. Or, the iron may lead by 3 ins. on the north side and the shield lead by ½-in. from the true square line on the south, in which case it would be said that the iron has a lead of 3 ins. on the north and the shield a lead of 3½ ins. on the south. It might be thought that a lead on the iron, once obtained, would be carried along indefinitely, the joints between the segments of a ring being all machine faced; but such is not the case; the machining of the segments cannot be absolutely true and their widths not absolutely alike, and it is found that small quantities of dirt get into the joints, especially at the bottom, and thus the leads are constantly altering. Nor indeed is it desired to constantly maintain the same leads, as the nature of the ground being a constantly changing factor the leads have to be altered to meet changed conditions.

The leads of the lining are changed by building in special rings (taper rings) as described previously under the heading of Tunnel Lining. The lead on the shield is obtained or altered by means of the shoving rams; that is to say, if it is desired to have 2 ins. lead on the north side of the shield, the rams on the north side are shoved out 2 ins. more than those on the south, and similarly for top and bottom leads. In order to make sure that the lead on the shield is effective it must be obtained early in the shove and maintained till the end of the shove; and this has to be watched, as carelessness on the part of a foreman will cause him to keep to the letter but not the spirit of his instructions, by shoving regardless of leads and then when the shove is complete manipulating the jacks so that it appears that the leads asked for have been obtained.

The horizontal lead of the iron is determined by measuring from marks at right angles to the axis of the tunnel (fixed on boards fastened to the sides of the tunnel) to the machined face of the last ring erected. The vertical lead or inclination is obtained by lowering a plumb bob from the top machined face of the front flange of the last erected ring to a point opposite the lower flange, and reading the distance from the bob to the lower machined face, then subtracting or adding the amount due to the grade of the true line. The leads of the shield are obtained by measuring from the front machined face of the last ring erected to the shield diaphragm at top, bottom and sides.

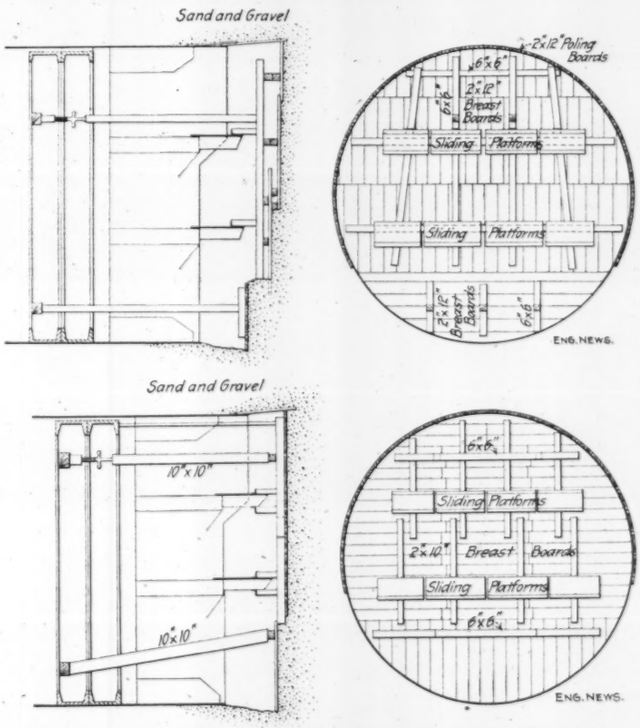


FIG. 31. TWO METHODS OF TIMBERING THE BREAST IN FULL FACE OF WET SAND, GRAVEL AND BOULDERS.

The vertical breast-board method (upper sketch) was first tried. The horizontal breast-board method (lower sketch) was adopted.

Speaking generally, throughout the portion of the tunnel in sand, gravel and boulders it was necessary to keep a 2-in. bottom lead on the iron, with an additional ½-in. lead on the bottom of the shield, to maintain true grade.

E. IN SILT.—With the entry of the shields into the true Hudson River silt, the real interest and difficulty of shield guidance began. There was considerable hope that on reaching this material it would be possible to close the shield face entirely and travel across the river without taking in any ground at all, for the reason before noted in this article.

The Weehawken headings of the Pennsylvania tunnels were the first to pass the river line and enter upon unobstructed Hudson River silt; the hoods of the shields were removed, cutting edges completed round the whole circumference, all doors closed and the shield pushed. Immediately this was done, serious complications in the way of maintaining grade arose; despite a heavy top lead on both iron and shield, the tunnel would not follow the grade but rose at each shove. When the safe limit of top lead had been reached* the tunnel still refused to follow grade. A halt was called and the whole situation reviewed. Finally it was decided that the displacement of such a large volume of mud by the forcible shoving of a closed shield through ground of this sort caused the displaced mud to move in the direction of the line of least resistance, i. e., upwards, that the upward movement of this ground would cause the shield to rise with it, and that this could only be checked by not having the shield closed but having one or more doors open during the shove, thus allowing the ground to flow into the tunnel. This was done and the effect was instantaneous; trouble due to this ceased, though the constantly varying nature of the ground called for incessant watchfulness on the part of those charged with the responsibility of keeping the tunnels true to line and grade.

The character of the ground was also such that other phenomena became apparent with further experience, such as (a) rise of the iron on leaving shield (b) distortion, and (c) action of one tunnel being driven alongside one previously constructed on the latter or both. All these phenomena varied with the amount of muck taken in through the shield; the less muck taken in the more marked the result. Each action will be briefly described, and it should be remembered that this deals only with shield driving in Hudson River silt.

a. Rise of Lining Behind Shield.—It was found that after the shield had been shoved, the lining when clear of the tail rose at once about 0.10 ft., and that the less ground taken through the shield the more this rise was marked. Thus by reducing the amount of muck taken in, not only could any tendency of the shield to go down too quickly be reduced but a low place in the tunnel just behind the shield could be corrected.

b. Distortion of Lining.—It was found that up to the river lines on both New Jersey and New York shores the iron lining had a tendency to flatten, i. e., the horizontal axis tended to increase while the vertical decreased, and to correct this turnbuckles were extensively used, to ensure a good shape immediately after erection, and to maintain it. On the river side of the bulkhead, however, the tendency was for a ring on erection to have the vertical diameter about 0.10 ft. larger than the horizontal, but as time progressed, the shape of each ring tended to improve, i. e., the vertical and horizontal axis gradually became more nearly equal.

c. Action of One Tunnel Being Driven Alongside Another Previously Constructed.—The

*The amount of lead of shield over iron is limited by the amount of clearance between the outside of the tunnel lining and the inside of the shield shell, while the inclination of the iron is limited by the clearance of the bolts in the bolt-holes.

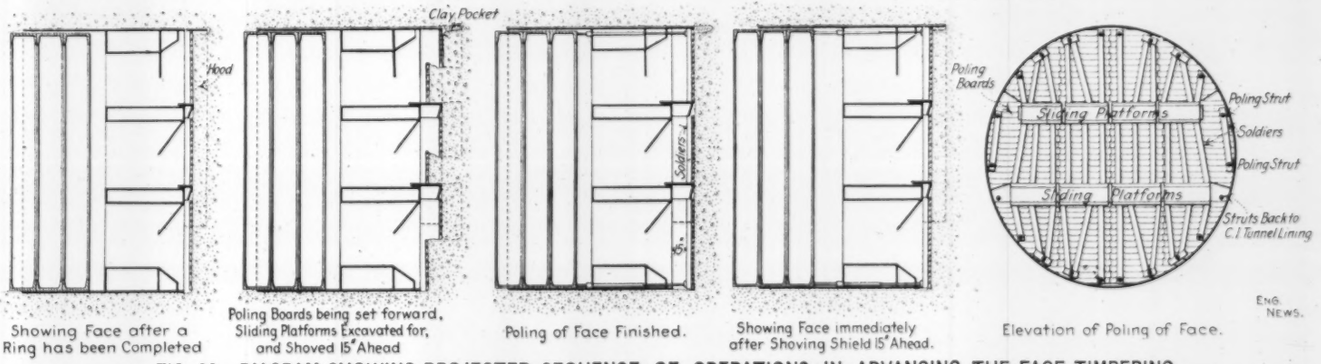


FIG. 32. DIAGRAM SHOWING PROJECTED SEQUENCE OF OPERATIONS IN ADVANCING THE FACE TIMBERING.

For 15-in. shove, with use of clay pocket around cutting-edge. The work was actually done by shoving a full ring-length (30 ins.) at a time, and employing roof poling-boards instead of the clay pocket, the other operations being substantially as here shown.

result of driving a shield alongside a tunnel previously constructed may be summarized as follows: (1) The previously constructed tunnel rises about 50 rings (125 ft.) ahead of the passing shield and continues to rise until it reaches a maximum elevation just after the other shield has passed it, at which point it is usually about 0.10 ft. above its lowest previous position, after which it gradually settles and returns to its lowest previous position about 150 rings (375 ft.) behind the passing shield. (2) There is also a lateral movement away from the passing shield; this movement averaged about 0.20 ft. when 60% of the total volume of ground displaced was being taken out through the passing shield, though 0.33 ft. has been observed. This lateral movement has since somewhat diminished. (3) There is a decrease in horizontal diameter with a corresponding increase in vertical diameter caused by the passing shield which reaches a maximum of about 0.07 ft. and occurs a short way behind the passing shield. The iron lining of the tunnel returns to the same shape it had before it was influenced by the other one, in from five to six weeks.

The measurements and figures given refer to the case when the passing shield was taking in from 50 to 60% of the mud displaced by the shield on each shove. If the amount taken in were reduced the effect on the adjoining tunnel would be more marked and vice versa.

The means adopted for the guidance of the shield in full silt resolve themselves therefore into a combination of varying the amount of muck taken in through the shield and varying the leads on both iron and shield.

From what has been said before on the subject of the behavior of the tunnels in the Hudson River silt, it will be seen that the amount of work thrown on the alinement staff was a heavy one. With the tunnels in a constant state of movement, both vertical and lateral, and also showing constant alteration in shape after original construction, all of which movement had to be precisely measured and recorded both for the purpose of gaining an insight into the forces at work which produced such results, and also for the purpose of maintaining true line and grade at the working faces of the tunnel; with an atmosphere of such density that an instrument sight of more than 200 ft. in length was a boon that was seldom accorded; and with the added burden of compressed air with its tedious locking in and out operations and its necessity for cramped positions for hours at a time in a small emergency lock; it seems highly creditable to bring the tunnels to a junction from shafts 6,600 ft. apart with an error in the working lines of only 0.008 ft. and an error in level of 0.04 ft.

At the same time it should not be forgotten that such efforts to furnish true lines and grades to which the work should be built are completely nullified unless efforts are put forward to build the work to such lines and the good results obtained in this direction bear equal evidence to the constant care and watchfulness exercised by the construction staff in the execution of their, sometimes, rather monotonous duties.

COMPLETING THE TUNNELS.

The work of erecting the iron lining during the advance of the shields involved nothing more than fitting the segments in place (their joint surfaces being left bare as taken from storage), and bolting up the joints. As the air-pressure in the tunnel approximated the hydrostatic head outside, the condition of any joint as to tightness against leakage was not evident at this stage. The nuts of the bolts were drawn up as tight as feasible. Occasional bolts were omitted to permit of attaching the brackets for the bolting-platform rollers and similar accessories.

Grouting was done extensively in the rock, sand and gravel and in exceptional cases in the silt behind the river bulkhead walls, where structures had to be respected. This grouting may be the means of making the tunnels somewhat more water-tight, although its main purpose was to maintain the stability of the ground and the tunnels within. About three-fourths of the total length of subaqueous tunnel was not grouted. After the completion of the lining from end to end, all the joints of the iron lining are being carefully calked, and from time to time the air-pressure is gradually reduced with a view to test the water-tightness. This calking with a mixture of iron borings and salammoniac is now well advanced.

FIG. 33. AIR-BLOW FROM TAIL OF SHIELD AT RIVER BULKHEAD WALL, NEW YORK. MARCH 9, 1906.

The air-blow sometimes rose to 20 ft. above the water surface. It continued until the shield was about 300 ft. outstream from the bulkhead and was finally stopped by placing 16,000 cement-bags filled with silt over each tunnel.

Besides other minor work, two main items remain to be done before the tunnel is ready for track; putting down the foundation columns, and placing the concrete lining. Both are only on the point of being commenced, and meantime they therefore cannot be described.

The Survey Work.

Before concluding this article, a brief account of the survey work (triangulation and tunnel control) is here given.

Work was begun in November, 1901, with a view to locating the line of the proposed tunnels and fixing their length and direction. Two base-lines were established, one on each bank, nearly at right angles to the line of the tunnel and about 6,350 ft. apart. The Manhattan base, about 2,242 ft. long, lay along the west curb line of Eleventh Ave., and its intersection with the center line of the tunnels was taken as Sta. 200, the stationing to progress westward. The end-points of these bases and several auxiliary points on each bank were taken as station points for triangulation. The base-lines were measured with a 100-ft. steel tape, previously standardized; in use it was supported every 20 ft., a tension of 12 lbs. was applied by a weight working over a bicycle wheel, and the position of the forward end was marked on the brass top of a small heavy trivet or spider set on the ground. Angles were measured by repetition, in a large number of series, with several different observers; an engineers' transit with 7-in. horizontal circle and verniers reading to 10 sec. was used for this work. This work furnished a basis for computing the stationing of the Weehawken end of the tunnels. Permanent line monuments were set in prominent locations on both shores in the lines of the Manhattan and the Weehawken tangents. In connection with the early work, also, wash-borings and soundings in the river were made, to furnish data for the plans and bids.

The connection of levels on the two shores was accomplished by two methods, tide-gage comparison and direct leveling. Tide-gages were set up at both sides, and read at intervals of 2 mins. during slack water, and 5 mins. while the tide was running, for 31 days; from these readings the mean stage was computed, and this gave an elevation common to both banks. The method of direct sighting involved the use of an instrument and a rod on either side, with equal lengths of sight across the river, to eliminate the effects of curvature and refraction.

FIG. 34. SHIELD SHOVING IN HUDSON SILT, ONE DOOR PARTLY OPEN.

When the shafts had been completed and the tunnels were begun, the surface lines were transferred down the shafts to establish monuments in the tunnels. At the Weehawken shaft, which is directly over the tunnels, the procedure for this purpose was relatively simple. Brass plugs were set in the coping of the east and west walls of the shaft on the line of the North tunnel, and from these, by means of a beam-compass of 37-ft. spread, similar plugs were set on the line of the South tunnel. Pairs of plumb lines were lined in with these plugs and transferred to permanent monuments set in the floor of the shaft, and from these the survey lines in the tunnels were prolonged.

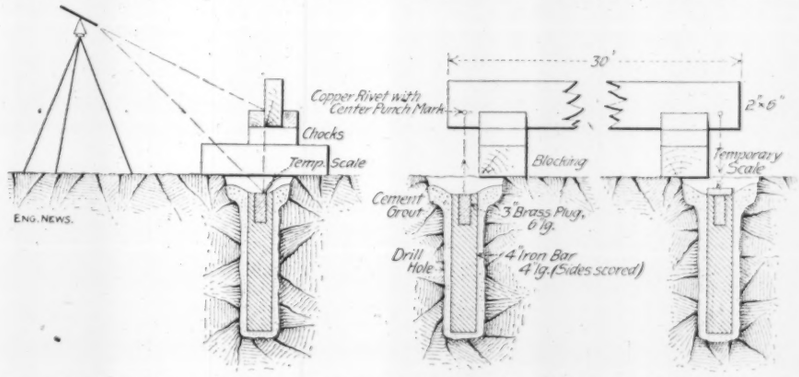


FIG. 36. PERMANENT ALINEMENT MONUMENTS IN TUNNELS, AND BEAM-COMPASS FOR TRANSFERRING ALINEMENT FROM NORTH TO SOUTH TUNNEL.

At the Manhattan shaft, which lies some distance off the tunnels, the procedure was less simple. A surface line at right angles to the tunnels was transferred down the shaft by two plumb lines carrying 30-lbs. weights suspended in water. Underground, this line was prolonged to the tunnels, and right angles turned, from which plugs were set in the rock floor to mark the tunnel line. About 500 ft. in length of tunnels were controlled from these plugs. Just before the beginning of the shield work, a more precise transfer was made. Two 10-in. pipes were sunk to rock, and 8-in. holes drilled through them to the tunnel, at points about 158½ ft. apart and on a line parallel to the axis of tunnels, 2.7 ft. south of the center line of the North tunnel. Plumb lines through these holes served to establish permanent monuments in the rock floor of the tunnel, thus giving a base-line of 158½ ft. for prolonging a line about 3,400 ft. long. These monuments were constructed as shown in the sketch Fig. 36. The sketch also shows the method of setting from the North tunnel monuments, monuments for the South tunnel by means of a beam compass. The exact marking of the desired point on these monuments was done by drilling a small hole in the top of the 3-in. brass plug.

In this work of establishing triangulation stations and line plugs, as well as in the later work of prolongation in the tunnels, it was made a universal practice to use an auxiliary transit for transferring plumb lines to plugs and plug points to plumb-lines or transits. Fig. 36 indicates the application of this method to transferring the end point of a beam-compass to a permanent monument. A flat beveled-edge scale was laid on the top of the plug, and the transit, which was first sighted on the beam-compass mark, read on the scale the exact position of the point, thus making it possible to scratch the station mark on the plug with very great accuracy. In setting up transits over or under station marks (the station marks in the lined tunnel were fixed in the roof), the auxiliary-transit method proved of very great service.

SURVEY WORK IN TUNNELS.—The survey work up to this point was in charge of an alinement engineer, but when the surface lines had been transferred into the tunnels this position was abolished and survey corps were established at Weehawken and Manhattan, each under an assistant engineer reporting to the respective resident engineer. These corps each consisted in the beginning of about five men, but they were gradually increased as the work progressed, reaching a maximum of about 20 men each. Each corps was in general divided into four parties: a Precise Line corps, under a chief of party; a night and a day Checking corps, each under a transit-man; and a Level corps, under a leveler. After the junction of the shields, the two corps were placed under the direction of one assistant engineer, reporting as before; they consist at present of 15 men each.

The precise and check line work (alinement) and the longitudinal measurement (stationing) were carried on over an auxiliary platform 7 ft. below the roof of the tunnel, on a level with the emergency locks of the bulkheads (see Fig. 20, p. 613, Eng. News, Dec. 13, 1906). Transit-tables were bolted to the top segments of the lining at intervals of about 150 to 200 ft., as shown in Fig. 37, and immediately above each table a station point or scale was fixed to the roof either by bolting or by concreting. In the Manhattan tunnels, levels were run from the transit tables, using as bench-marks certain raised letters cast on the B-segments of the lining. In the Weehawken tunnels, the levels were run from level-tables bracketed to the side of the tunnel near the lower or working platform, over bench-marks consisting of a track-spike set in concrete in an angle of the lining (Fig. 37). The latter arrangement enabled the leveler to take readings directly on rods held on roof and invert, the Manhattan arrangement requiring the elevation of invert to be obtained by taping the vertical diameter.

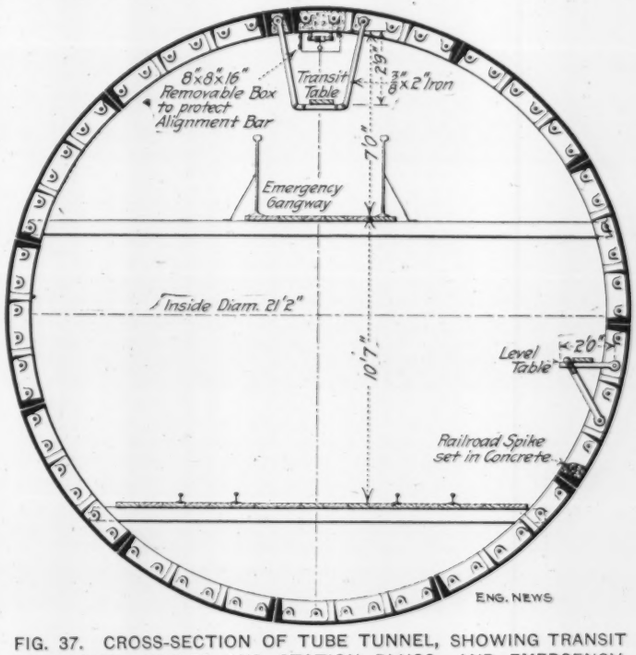


FIG. 37. CROSS-SECTION OF TUBE TUNNEL, SHOWING TRANSIT AND LEVEL TABLES AND STATION PLUGS, AND EMERGENCY GANGWAY.

The line work involved prolonging the line of the tunnel, from the permanent monuments in the rock section, through the emergency locks, to the last station point in the tunnel, which would be about 50 rings (125 ft.) behind the shield. Such lines were run at intervals of three to four months in the early stages, but later at intervals of one month. Check lines were run at weekly or fortnightly intervals. All this work was done by the following method: Setting the transit accurately in the plane of the survey line (in the Manhattan tunnels the survey lines were offset 2 to 3 ft. from the tunnel center lines) by the use of an auxiliary transit, a back-sight was taken on the preceding station point; then transiting the telescope direct and reversed, a plumb-line hung from the scale of the next station point ahead was set in the survey line. When accurately set, the position of this plumb-line was read on the scale and the reading noted. The difference between this reading and the last previous reading on the same scale gave directly the amount by which the corresponding point of the tunnel had moved laterally in the interim. Leaving the plumb-line in place where set, the transit was then carried forward and set accurately under the bob, and the whole process repeated to set a line at the next station point.

The station points or scale-plugs went through several stages in their evolution. The first type (A, Fig. 38) had a scale 1-in. long fastened near the lower edge of a brass block set in concrete in the roof. When the tunnel entered soft ground, a longer scale became necessary, and a wider plug of similar form bearing a 3-in. scale was constructed (B, Fig. 38). After the tunnels had entered some distance into the Hudson silt, it was found that a still longer scale was desirable, as larger lateral motions of the tunnel occurred here. A 6-in. vernier scale was then adopted, arranged as at C, Fig. 38, and this type was used up to the completion of the work with great satisfaction. The 1-in. and 3-in. scales were graduated to $^1/_{50}$-in. The vernier scale was graduated to $^1/_{100}$-ft. and could be read by the vernier to 0.001 ft.

The two photographs, Figs. 39 and 40, shows a station-point of this last type during the process of lining-in. When not in use the scale was protected by a padlocked box, attached to hasps which appear in the view. The light-box which forms the background for the plumb string in the photograph was also developed by trial. The first background or light-box used consisted of a box across whose open front was stretched a sheet of tracing-cloth illuminated by four electric incandescent lamps inside the box. This, though extensively used in other tunnel work in the past with satisfaction, was, however, discarded for a more efficient arrangement. A box was then designed about 20 ins. square by 6 ins. deep with two lamps in each side concealed behind front boards leaving a vertical slot in the center through which reflected light from the white enameled interior walls was seen. This design proved very satisfactory, except that under some conditions the power was too low. Similar boxes containing 6 and 8 32-c.p. lamps were then

made, and used with full success, the 8-lamp boxes being required only for specially long sights.

For the "precise" alinement work, each setting of instrument or plumb-line was made to depend on a large number of independent settings both direct and reversed. In carrying the line through the air-locks, in all cases the lock-door through which the sight was taken was open; as the repetition of backsights and foresights here with a single observer involved his changing pressure for each sight, the plan of using two observers was adopted. The first observer, on the low-pressure side, took the backsights, and then, stepping out of the lock, closed the door, whereupon the observer on the pressure side admitted air to the lock and set the foresight plumb-line by the transit as set. Closing the inner door and emptying the lock, the first observer reversed the instrument and again set on the backsight, enabling the second observer to complete the pair of settings as described. For a long time, too, the fog was so troublesome that sights longer than 200 ft. were rarely possible and this distance was adopted as the interval of alinement stations. When the second bulkhead was in, halving the pressure drop at each, the air became much clearer and sights of 400 ft. could be taken, so that alternate stations were omitted in the prolongation of precise lines.

The horizontal curves in the tunnels were laid out by tangent offsets. As the intersection point fell inside the tunnel in each case, the instrument could be set up on this point and the new tangent set out by turning the angle.

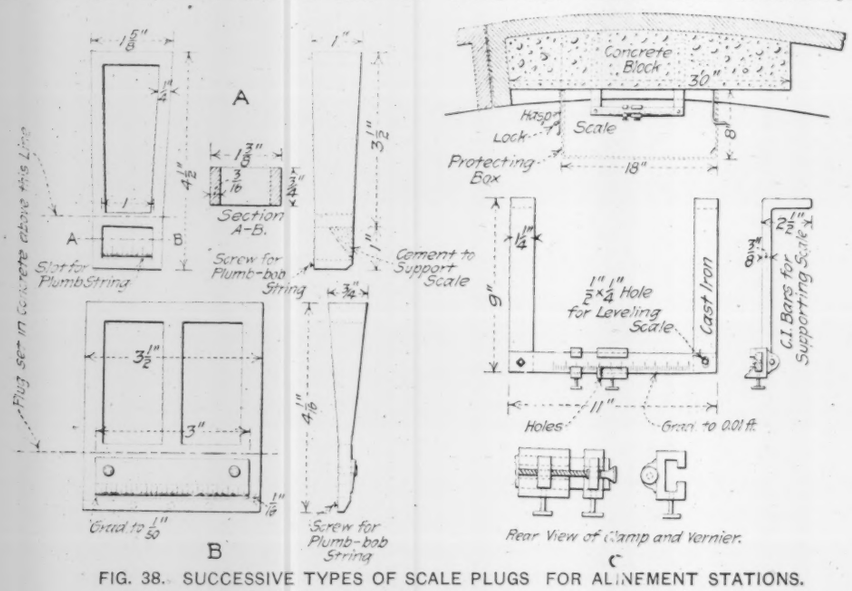


FIG. 38. SUCCESSIVE TYPES OF SCALE PLUGS FOR ALINEMENT STATIONS.

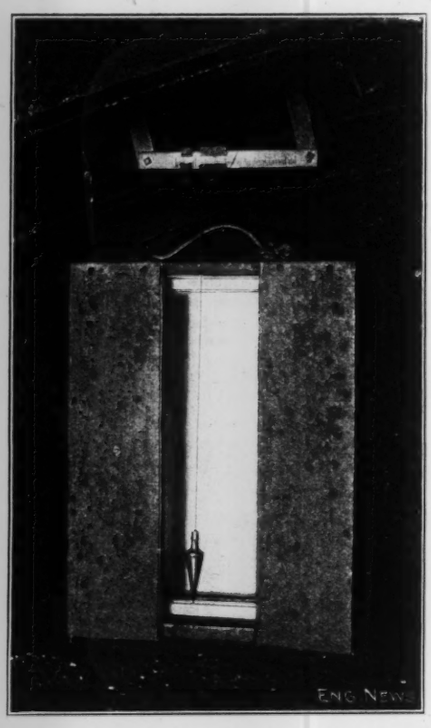


Fig. 39. View of Six-Inch Vernier Scale Plug and Light Box.

Intermediate points were set in the tunnel roof between precise-line plugs for the stationing or longitudinal measurement. Measurements were made between plumb-lines suspended from these points and the scale-points. In the Manhattan tunnels, the tape was suspended on the tunnel grade, supported at the ends only, and a tension of 20 lbs. was applied; several readings were taken at each end and their mean corrected for temperature, sag, tape-unit, and grade. At Weehawken the measurement was horizontal, the tape was supported every 20 ft. by an adjustable hanger, and a tension of 12 lbs. applied; correction for temperature and tape-unit only being necessary. Each tunnel was stationed twice, and where appreciable differences were found a third measurement was made.

Levels were run from the rock each week. Readings were taken at every tenth ring, on the front flange of both invert and roof. Horizontal diameters were also taken. Measurements of chords between specified bolt-holes were also taken at these rings, to serve as a rough check on the distortion. For ordinary levels, Philadelphia rods graduated to 1/100-ft., 6, 13 and 16 ft. long, were used, both with and without targets. For precise levels New York rods with targets and rod-levels were used.

SHIELD CHECKING.—For the purpose of checking the position of the shield and iron at the face, regular measurements were taken about every four rings (10 ft.). Two corps were employed, one at night and one during the day, and two or three checks were made in each tunnel each day.

Opposite the last transit table (not over 50 rings from the face) two pieces of board were wedged in the iron at axis level, and points were marked on these boards at right angles to the center line and opposite the station. From these points measurements were taken to the front ring of lining on each side, their average giving the station of the front ring, while their difference gave the side lead of the iron. The alinement of the front ring was obtained by sighting a temporary point on the front top flange (from the last transit table, with backsight on the preceding scale-point), lowering a plumb-line, and measuring to both sides of the lining. The roll of the iron was obtained by measuring the relative positions of bottom and top middle bolt-holes by means of this plumb-line.

Vertical and horizontal diameters were also taken, and also elevations of inside of flange (top or bottom) by leveling from the last bench-mark (not over 100 rings behind the face). The latter figure, by comparing with the desired elevation corresponding to that ring, gave the vertical deviation of the tunnel. The tenth and twentieth rings from the face were also checked in elevation and in horizontal and vertical diameter. (On the twentieth ring back of the face a system of chord measurements was also taken, to test more fully for deformation). The overhang or inclination of the front ring of lining was found by suspending a plumb-line from the front face of the leading ring at the top and measuring the distance from this line to the lower flange. The position of the shield, as concerns side lead and inclination, was obtained by measuring to the last ring of lining.

The record of these check surveys was made in special note-books whose pages were blank forms for all the required observations and computed data. Included in the notes were the number and location of any special rings used, the air-pressure and temperature at the shield, and the amount of carbon dioxide in the air; the latter was determined by taking a sample which was tested later in the office. From the note-books the data were entered on filing cards kept in the office. Another card, giving only the deviation in line and level of the last ring, and lead and inclination of iron and shield, was prepared at the same time for the shield inspector, and on this card the resident engineer wrote his instructions as to the guidance of the shield.

CHECKS ON UNDERGROUND LINES.—When the tunnels had advanced under the river, a check on the line of one tunnel on either side was made just landward of the river wall, by sinking a pipe to the top of the iron, drilling through from below, suspending a plumb-line in the hole, and comparing this line with the surface and the underground lines. Near the same point on either bank a 6-in. pipe was driven across from North to South tunnel, and the distance between center lines measured. In the Weehawken side a second pipe between tunnels was driven about 1,000 ft. farther out. None of these checks showed discrepancies large enough (especially as the surface check lines could not be run very precisely) to make any change in the underground working lines desirable, with one exception: The measurement of distance apart, through the pipes between tunnels on the Weehawken side, led to the conclusion that the

Fig. 40. Transit in Position on Transit Table.

North tunnel working line, Weehawken, was slightly out, enough to carry the North tunnel about 0.06 ft. south of its Manhattan mate at the estimated point of junction. This deduction was not used for making a correction of the working lines until the North shields were approaching their junction, when the shoving of the the view on the first page of this issue shows strikingly the accuracy of junction.

In the South tunnels the same procedure was gone through, except that the pipe put through (10-in.) was fairly level and parallel to line. A sight on an offset line through this pipe showed that the South Weehawken line was 0.03 ft. to greater in both tunnels by 0.954 ft. in the North and 1.053 ft. in the South tunnel.

Two precise-line checks for alinement have been run since the junction of shields, as part of regular monthly surveys now being conducted. The North tunnel working lines have been found to be 0.041 ft. and 0.0585 ft. apart,

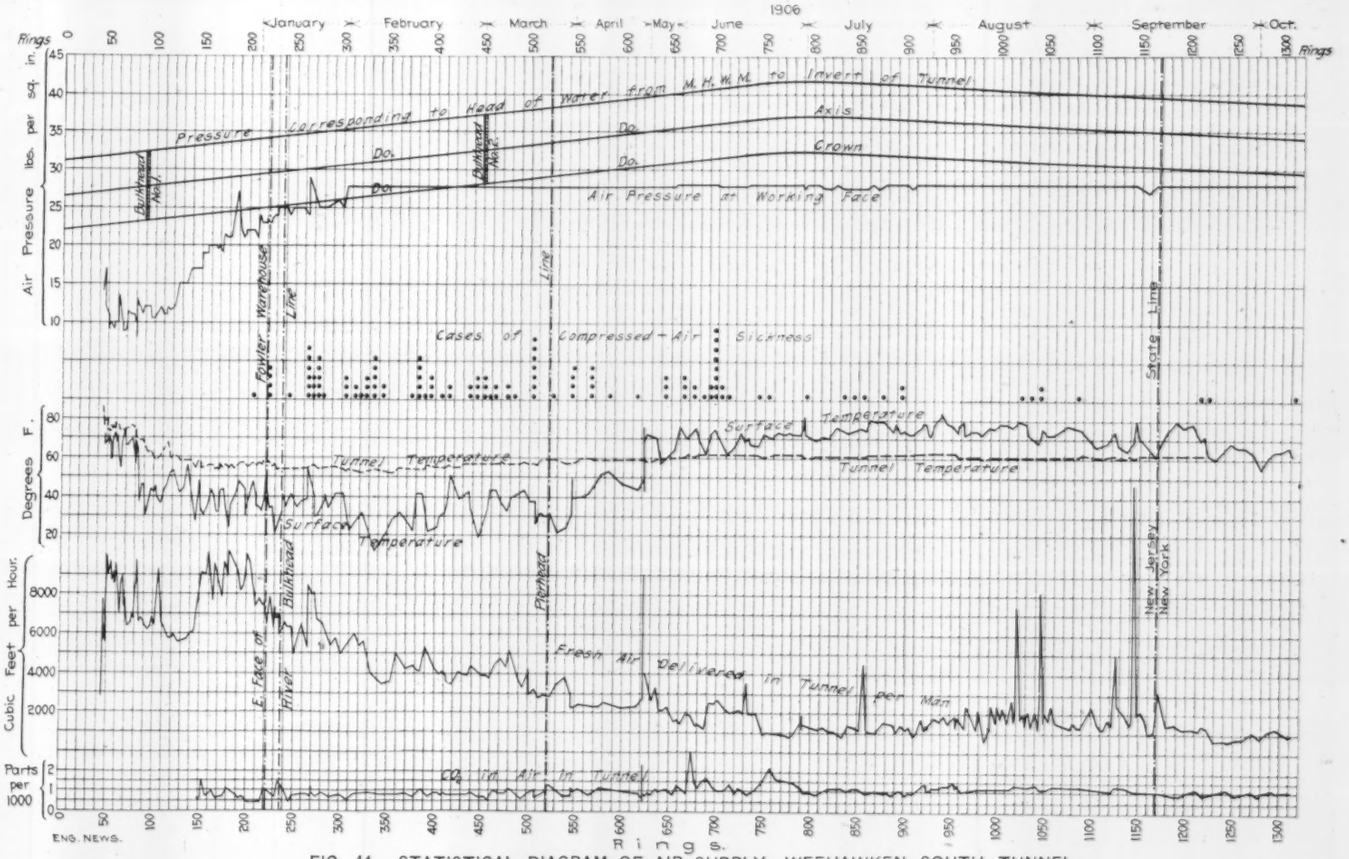


FIG. 41. STATISTICAL DIAGRAM OF AIR SUPPLY, WEEHAWKEN SOUTH TUNNEL.

Showing Pressure, Temperature, Volume, and Carbon Dioxide Contents, of Air Supplied to Heading and Number of Cases of Compressed-Air Sickness.

Weehawken shield was adjusted with the aim of carrying it a corresponding amount northward.

A check of somewhat different nature was made when the shields were approaching junction. The two Weehawken tunnels had been driven nearly abreast, while the North Manhattan tunnel was several hundred rings ahead of the South. When the two North shields were 126 ft. apart they were stopped and the South Weehawken shield was driven past the end of the North Manhattan tunnel, lapping about 74 ft. A 6-in. pipe was then driven from it to the North Manhattan tunnel and check measurements made for level and distance apart. The lines were found to be 37.0032 ft. apart, an error of 0.0032 ft., thus confirming the belief that the discrepancy noted through the Weehawken cross pipes was due to the North line. The checks for level and line were so nearly correct that the two North shields were at once started toward each other.

JUNCTION OF SHIELDS.—When the North shields were about 10 ft. apart at the cutting edges, a 10-in. pipe was driven from one to the other through the northerly door of the middle tier, to afford a direct check of lines and levels. But this pipe was broken in driving, and when finally put through it was on such a slant that the field work of a check would have delayed progress too much. The two shields were therefore shoved in the regular working lines, except that allowance was made for the 0.06 ft. by which, it was believed, the Weehawken shield was too far south. When the cutting edges were about five feet apart, the pipe gave a level sight through, and it was found that the Weehawken levels were 0.06 ft. lower than the Manhattan levels. On this basis the shields were pushed together, and they met as squarely as is possible; the north of the Manhattan line, and its levels were 0.03 ft. lower. On this information the shields were pushed forward to a junction as close as that of the North tunnel.

The checks prior to the actual junction of the shields were all more or less affected by the shoving of the shields and the inability of the corps to get simultaneous levels and lines to the checking points. After the removal of the shields, a precise-level check was run to the middle of the river by both corps; they differed by 0.045 ft. in the North tunnel and 0.030 ft. in the South tunnel, the Manhattan levels being the higher in both cases. The mean of these two figures can be taken as the error of the original level transfer across the river. A line-bar near the state line was tied in to the precise stationing of both corps, and showed that the Weehawken stationing was in the two surveys, the Weehawken line being to the south in both cases. The South tunnel has given figures of 0.0013 ft. and 0.0154 ft., an average of 0.0084 ft.; in this case also the Weehawken line is more southerly.

Rates of Progress in Driving Tunnels.

Below is given a table (Table III.) of some of the main dates connected with the tunnels. From these dates the time occupied by the several sections of the work may be deduced, and therefrom the average rates of progress. The latter, however, have little meaning unless much more fully subdivided. In Table IV., therefore, the work is classified according to material passed through and other conditions, together with the average daily advance for each. Finally, in order to eliminate the influence of

TABLE III.—PRINCIPAL DATES, PENNSYLVANIA R. R. HUDSON (NORTH) RIVER TUNNELS.

	N. Manhattan	N. Weehawken	S. Manhattan	S. Weehawken
Shaft and preliminary headings commenced	June 10, '03	June 11, '03		
Shaft and preliminary headings finished	Dec. 11, '03	Sept. 1, '04		
Excavation of shield chamber begun	May 24, '04	Jan. 6, '05	May 24, '04	Jan. 16, '05
Excavation of shield chamber finished	Jan. 21, '05	Mar. 25, '05	May 13, '05	Apr. '05
Cast-iron lining of shield chamber begun	Feb. 4, '05	none	May 15, '05	none
Cast-iron lining of shield chamber finished	Mar. 13, '05	none	June 14, '05	none
Excavation of tunnels begun before installation of shield	Oct. 17, '04	Jan. 13, '05	Jan. 5, '05	Jan. 25, '05
Shield parts received at shaft	Mar. 11, '05	Mar. '05	June 22, '05	Apr. '05
Erection of shield begun	Mar. 13, '05	Mar. 27, '05	June 22, '05	Apr. 24, '05
Erection of shield finished	May 12, '05	May 28, '05	Aug. 27, '05	June 13, '05
First ring of permanent c-i. lining put in	May 12, '05	May 29, '05	Aug. 27, '05	June 14, '05
First air-lock bulkhead wall begun	May 29, '05	June 15, '05	Sept. 18, '05	June 21, '05
First air-lock bulkhead wall finished	June 7, '05	June 23, '05	Sept. 23, '05	July 3, '05
Air pressure first put in tunnel	June 25, '05	June 29, '05	Oct. 6, '05	July 8, '05
Rock disappeared from invert of tunnel	Dec. 1, '05	Oct. 31, '05	Feb. 8, '06	Sept. 21, '05
First pair of bore segments built in tunnel	Dec. 9, '05	Jan. 12, '06	Feb. 16, '06	Dec. 12, '05
Riprap of river bulkhead wall first met	Feb. 8, '06	none	Apr. 11, '06	none
First pile met (in river bulkhead wall at Manhattan, and Fowler warehouse foundation at Weehawken)	Feb. 18, '06	Jan. 3, '06	Apr. 18, '06	Dec. 4, '05
Last pile met	Mar. 2, '06	Feb. 5, '06	May 1, '06	Jan. 9, '06
First ring erected on river side of shore line	Mar. 3, '06	Feb. 4, '06	May 4, '06	Jan. 17, '06
Removing hood of shield: from	Mar. 27, '06	Feb. 6, '06	May 9, '06	Jan. 19, '06
Removing hood of shield: to	Apr. 1, '06	Feb. 8, '06	May 12, '06	Jan. 24, '06
Second bulkhead wall begun	May 12, '06	Mar. 19, '06	July 13, '06	Mar. 11, '06
Second bulkhead wall finished	May 21, '06	Mar. 24, '06	July 21, '06	Mar. 18, '06
Tunnel holed through with meeting tunnel		Sept. 12, '06		Oct. 9, '06
Last ring of permanent c.-i. lining built in		Oct. 9, '06		Nov. 18, '06

interruptions and extraneous delays, the *maximum* daily rates of progress in the different materials are listed in Table V.; to each is appended a statement of the heading which made this progress, the air-pressure, and the percentage of full excavation taken out.

It should be said that the average speeds of progress, Table IV., are calculated from the days actually spent in shield work (i. e., not counting non-working Sundays or other holidays). A special entry, No. 9, is given to passing under Pier 62, where piles were encountered, for the reason that some delay was caused owing to the extra care necessary at this point to avoid disturbing the pier at present used to support the disposal trestle which extends from the site of the New Terminal Station at Ninth Ave. It is remarked also that, in Table IV., the progress under Ref. No. 11 (full silt face under river with heavy lining) has been affected by the fact that considerable difficulty has been experienced with keeping up the supply of lining segments, so that an average of

TABLE IV.—RATES OF PROGRESS, PENNSYLVANIA R. R. HUDSON (NORTH) RIVER TUNNELS.

Ref. No.	Type of excavation.	Rate of progress in lin. ft. of tunnel driven and lined per 24 hrs.
1	Rock excavation prior to installation of shield, including time thus spent (Manhattan and Weehawken)	1.02
2	Rock excavation in front of shield (Manhattan only)	2.47
3	Rock excavation in part rock face; soft ground from crown to axis, rock below axis (Manhattan only)	2.04
4	Rock excavation in part rock face; rock sloping down from roof to invert; silt above, Manhattan; sand above, Weehawken	2.50
5	Silt face on shore side of river bulkhead (Manhattan)	8.88
6	Sand and gravel face (Weehawken)	5.82
7	Sand and silt face obstructed by piles (Weehawken)	5.97
8	Silt face obstructed by riprap and piles, (Manhattan)	4.77
8a	Silt face obstructed by piles (Weehawken)	
9	Passing under Pier 62, North River (Manhattan)	11.80
10	Full silt face under river with light lining (Weehawken)	12.71
11	Full silt face under river with heavy lining (Manhattan and Weehawken)	14.42

TABLE V.—MAXIMUM RATES OF PROGRESS, PENNSYLVANIA R. R. HUDSON (NORTH) RIVER TUNNELS.

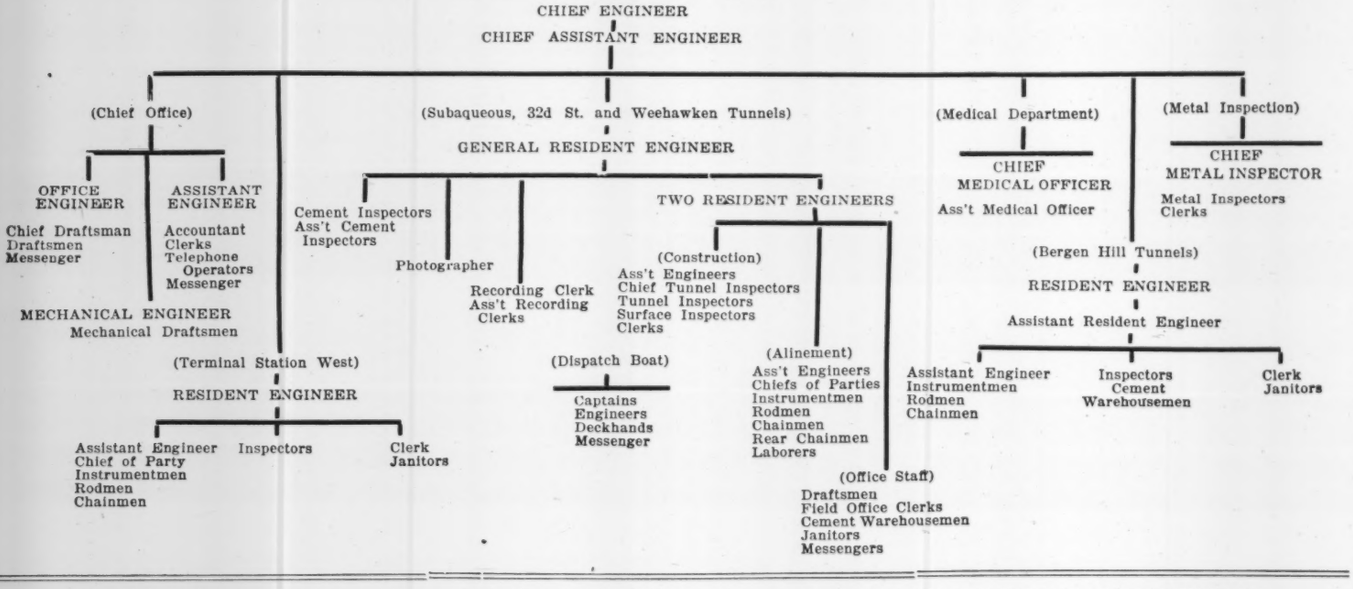
Reference No.	Maximum progress by any one shield per 24 hours.	Shield by which this progress was made.*	Percentage of full excavation taken out.	Air pressure at working face, lbs. per sq. in.
1	8 rings = 20 ft.	M.N.	100	Normal
2	2 " = 5 ft.	M.N and M.S.	100	8 to 14
3	2 " = 5 ft.	M.N. and M.S.	100	8 to 22
4	3 " = 7.5 ft.	M.S.	100	17
5	5 " = 12.5 ft.	M.N. and M.S.	96	15 to 20
6	4 " = 10 ft.	W.N. and W.S.	100	13 & 16
7	3 " = 7.5 ft.	W.N. and W.S.	100	13 & 20
8	3 " = 7.5 ft.	M.S. and M.N.	100	24
9	11 " = 27.5 ft.	M.N.	none	22
10	15 " = 37.5 ft.	W.S.	none	28
11	15 " = 37.5 ft.	W.S.	11.2	28

*N. means north; S. means south; M. means Manhattan; W. means Weehawken.

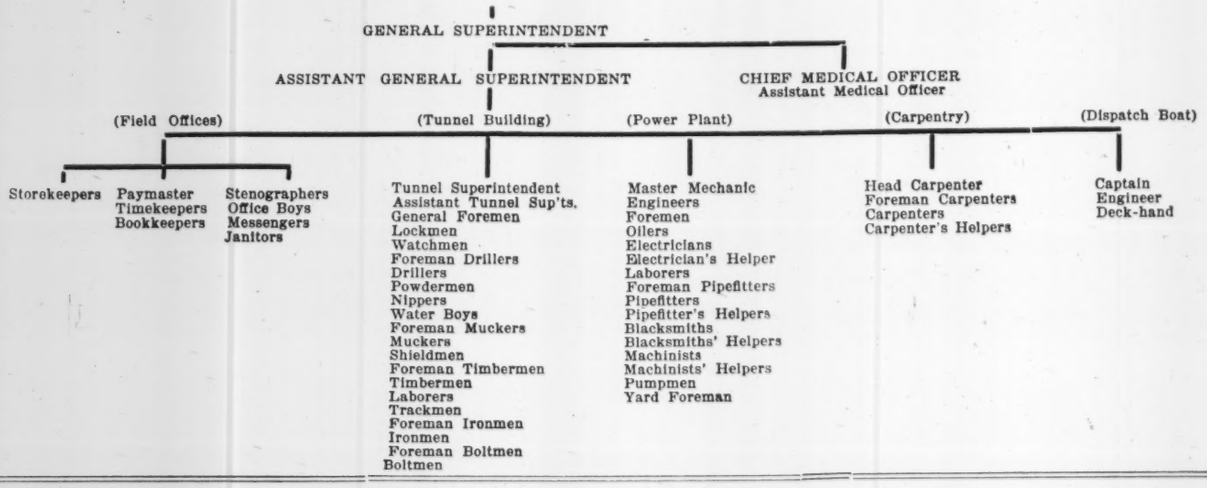
The Chief Medical Officer was assisted by a Resident Doctor, who was always at hand, day and night, on the work. These officers acted for both the Engineer and the Contractor.

P., N. Y. & L. I. R. R.—P., N. J. & N. Y. R. R., PENNSYLVANIA RAILROAD TUNNELS, NORTH RIVER DIVISION.

ENGINEERING STAFF ORGANIZATION



CONTRACTOR'S FIELD ORGANIZATION, PENNSYLVANIA R. R. HUDSON RIVER TUNNELS, O'ROURKE ENGINEERING CONSTRUCTION CO.



only two 8-hr. shifts per 24 hrs. has been worked on this section. The same remark bears on the maximum rate of progress under Ref. No. 11 in Table V.

Medical Care of Field Staff.

For the purpose of taking care of the cases of compressed air sickness, there was appointed a Chief Medical Officer, Dr. A. J. Loomis, who has had probably more experience in this line of work than any other medical man. To his care in selecting only those fit for such work and the good sense of the Contractors' management in implicitly being guided by his medical advice, a great deal of the remarkable immunity from serious sickness which this piece of work has enjoyed, may be ascribed.

Since the beginning of the work there were examined 8,500 men applicants for compressed air work. Of these about 6% were rejected as being unfit for such work. There have been 490 well-marked cases of compressed-air sickness, equal to about 6% of the number of all men employed, of which 9 were severe and 5 very severe. By "very severe" it is meant that these men would have

probably died had there not been skilled medical attendance to cope with the case at once.

The specifications were carefully drawn to obtain good atmospheric conditions in the compressed air tunnels. The amount of carbonic acid gas in any working face was limited to one part in 1,000 parts of air, and this amount was usually adhered to, being sometimes slightly under and sometimes slightly above, the average being the one part specified.

The Contractors were also called upon to provide suitable quarters for their men, provided with baths, lockers and all other conveniences, together with a supply of hot coffee on hand at all times. There were also provided two hospital locks at each shaft, one for the use of the Contractors' force and one for the use of the Engineering Staff, and these locks proved very useful in relieving cases of "bends."

A diagram is given on p. 231 illustrating the relationship of the various conditions of air pressure, temperature, purity of air, etc., in one of the four headings, which will also to some extent give an idea of conditions leading to compressed-air sickness. This diagram, extending as it does for a year, is necessarily to a small scale as regards time, and does not show the high peaks of air pressure when it would for a day or two, under exceptional circumstances, reach a maximum of 37 lbs., or, as frequently occurred, was

TABLE VI.—COMPARATIVE STATEMENT GIVING PARTICULARS OF SOME OF THE PRINCIPAL RAILROAD TUNNELS CONSTRUCTED UNDER WATERWAYS.

Name of Tunnel.	Method of Construction.	Dates. Work begun.	Dates. Work finished.	Distance from Shaft to Shaft, Feet.	Width of Waterway, Feet.	Depth to Invert of Tunnel, Feet.	Maximum Depth of Water, Feet.	Number of Tunnels.	Size of Tunnel.	Single or Double Track.	Nature of Lining.	Air Press. used in construction, lbs. per sq. in. above normal.	Nature of Ground Passed Through.
Thames, England	Sectional Shield	1807	1843	1,200	980		40	1	37' 6"x 21' 3"	Double	Brick in Cement	Normal	Gravel, Sand and Clay
Severn, England	Bottom, Heading and Break up	1873	1886	22,826	11,880		96 H. W. 60 L. W.	1	About 26' Span Arch	Double	Brick in Cement	Normal	Limestone, Sandstone, Marl, Sand, Gravel
Hudson, U.S.A. N. Y. & J. R. R.	Shield in 1891	1874	1905	5,650	5,500	97	60	2	19' 6" exter. dia.	Single	Cast Iron and Concrete	35 Average	Hudson Silt, Sand, Rock
Mersey, England	Hand Drilled	1881	1886	5,310	3,960	160	100	1	30' 6"x 28'	Double	Brick in Cement	Normal Enormous Pumping	Rock
City and South London, Eng. No. 1	Shield	1886	1890	Shaft in River	990	75	30	2	10' 11" external dia.	Single	Cast Iron	Normal	Blue London Clay, Gravel, Sand
St. Clair, Canada and U. S. A.	Shield	1888	1891	6,000	2,290	77	40	1	21' 0" external dia.	Single	Cast Iron and Concrete	10 to 28	Blue Clay
Waterloo and City Ry., England	Shield	1894	1896	Shaft in River	960	63	24	2	13' 0" external dia.	Single	Cast Iron	24	Clay, Gravel, Sand
City and South London, Eng. No. 2	Shield	1897	1900		1,000	75	30	2	12' 6" external dia.	Single	Cast Iron	Normal	Blue London Clay
Baker St. and Waterloo, Eng.	Shield	1900	1901	Shaft in River	1,050	70	38	2	12' 9¾" external dia.	Single	Cast Iron	10 to 35	Clay, Gravel
East Boston, U. S. A.	Roof Shield	1901	1903	4,300	2,250	90	47	1	28' x 25'	Double	Concrete	18 to 25	Sand, Clay, Gravel
Harlem River, U. S. A.	Sunk in sections within cofferdam	Sept. 1901	Sept. 1904	641	400	46	30	1		Twin	Cast Iron and Concrete	Normal	Mud, Silt, Sand
Penn. R. R. Hudson River, U. S. A.	Shield	1903		6,590	4,432½	97	53	2	23' 0" external dia.	Single	Cast Iron and Concrete	15 to 37	Hudson Silt, Rock, Sand, Gravel
Penn. R. R., East River, U. S. A.	Shield	1904		3,916	3,516	88	50	4	23' 0" external dia.	Single	Cast Iron and Concrete	25 to 35	Rock, Gravel and Sand
Hudson and Manhattan R. R.	Shield	Jan. 1906		5,978	5,100	92	60	2	16' 7" external dia.	Single	Cast Iron	19 to 42	Silt, Rock, Sand
Rapid Transit, Battery, E. R.	Shield	1902	1907	6,550	4,150	95	47	2	15' 6" internal dia.	Single	Cast Iron and Steel		Rock, Sand, Clay
Metropolitan, Paris (Seine)	Caissons in Water, Shield under land	1905	1907	3,584	1,325	40	16	1	24' x 18" int.	Double	Steel and Concrete		

TABLE VII.—COMPARATIVE STATEMENT GIVING PARTICULARS OF SOME OF THE PRINCIPAL TUNNELS (OTHER THAN RAILROAD) CONSTRUCTED UNDER WATERWAYS.

Name of Tunnel.	Method of Construction.	Dates. Work begun.	Dates. Work finished.	Distance from Shaft to Shaft, ft.	Width of Waterway, feet.	Depth to Invert of Tunnel, ft.	Maximum Depth of Water, ft.	Number of Tunnels.	Size of Tunnels.	Purpose of Tunnels.	Nature of Lining.	Air Press. used in Construction, lbs. per sq. in. above normal.	Nature of Ground Passed Through
First Chicago Water (L. Michigan)	Plain Excav.	1864	1866	10,567	....	about 70	about 35	1	5'	Water intake	Brick	0	Stiff blue clay
Washington St., Chicago (Chicago R.)	Cofferdam	1866	1869	.....	220	32½*	.....	Triple	36 x 11 (?)	Street	Brick	0	Clay
London (Thames).	Shield	1868	1869	1,320	1,020	.....	.....	1	8'	Pedestrian	Cast iron	..	Clay
First Cleveland Intake Tunnel. (L. Erie)	Plain excav.†	1869	1874	6,662	.....	67-90	36	1	5'	Water intake	Brick	0	Blue clay
La Salle St., Chicago Chicago R.)	Cofferdam	1869	1871	.....	276	.....	.....	Triple	..	Street	Brick	0	Clay
Second and Third Chicago (Water	Plain excav.	1872	1896	10,460 10,908	.....	.....	.....	1 ‖ 1 ‖	7'	Water intake	Brick	0	Stiff blue clay
Dorchester Bay Tunnel, Boston	Plain rock excav.	1880	1882	7,000	2 miles	144	.....	1	7½'	Sewage discharge	Brick	0	Rock
Hyde Park, Chicago (68th Street).(L. Michigan)	Plain §	1884	1898	5,026 11,167 8,132	.....	50-60	27-37	..	5', 6' and 7'	Water intake	Brick	..	Clay
New Croton Aqueduct. (Harlem R.)	Rock excav.	1887	1890	1,312	400	307	.....	1	10½'	Water conduit	Brick	0	Rock
Four-mile Chicago Water	Plain §	1888	1892	10,749**	.....	97	37	..	25,200 ft. 6 ft. ‖ 9,139 ft. 8 ft. ‖	Water intake	Brick	0-22	Gravel, hard-pan and clay
Vyrnwy, Mersey R. England. (Liverpool Water.)	Shield.	1888	1892	810	805	51	.....	1	10'	To carry water mains	Cast iron	17 to 25	Gravel, sand, clay.
Second Cleveland Intake (L. Erie)	.....	.....	1890	9,200	.....	.....	.....	..	7'	Water intake	Brick	.....	.....
Milwaukee Intake (L. Michigan.)	Plain §	1889	1895	3,200	.....	135	25	1	7½'	Water intake	Brick	26-30	Rock, clay and soft ground
Lake View Intake, Chicago.	Plain	1889	1896	10,000**	.....	70	.....	.....	6'	.....	.....	.....	....
Glasgow Harbor, Scotland.	Shield.	1890	1893	700	415	65	35	3	16' diameter.	2 roadway 1 footway	Cast iron	2½ to 18	Clay and sand
Van Buren St., Chicago. (Chicago R.)	Cofferdam	1890	1894	1,576	184	42*	18	1	About 30 x 20	Street	Brick	0	Clay
Blackwall, England.	Shield	1892	1894	1,221	1,041	81	39	1	27' external	Roadway and sidewalks	Cast iron and concrete.	15 to 35	Gravel, sand, clay.
East River Gas, New York.	Shield	1892	1894	2,516	1,700	110	65	1	11' external	For gas mains	Cast iron and rock	25 to 48	Rock and decomposed mica schists
Northeast Intake (Chicago).(L. Michigan)	Plains	1896	1899	14,025	.....	90	35	1	10' external	Water intake	Brick	0-30	.....
Berlin, Germany, (Spree R.)	Shield	1896	1899	1,490	.....	About 40	.....	1	13' 12"	Tramway	Cast iron and concr.	.....	Mud and sand
Third Cleveland Intake Tunnel. (L. Erie.)	Plains	1897	1906	26,000	.....	100	49	1	9'	Water intake	Brick	0-20	Clay
Cincinnati Water (Ohio R.)	Plain	1899	1901	1,426	.....	143‡	85‡	1	7'	Water intake	Vitrified Brick	.....	Rock
Greenwich, England.	Shield.	1900	1901	1,217	1,100	67	48	1	12' 9" external	Footway	Cast iron and concrete.	20	Silt, clay, gravel and sand
Rotherhithe, England.	Shield.	1904	....	1,600	1,400	78	40	1	30' external	Roadway and sidewalks	Cast iron and concrete.	22	.....

* Before the lowering, which has recently been completed.
† Short length by shield.
§ Part with air.
** One intermediate shaft.
‡ About 70 ft. less at low water.

raised for short periods ranging from half a day to two or three days at a time to the vicinity of 33 lbs.

The black dots, indicating cases of compressed-air sickness, it will be observed, seem almost without exception to accompany a sudden drop of temperature in the outside air.

The air pressure in ordinary conditions of working varied from 8 to 37 lbs. per sq in. above the normal atmosphere; for the most of the time it was from 25 to 30 lbs. per sq. in. above normal atmosphere.

The CO_2 gas in ordinary varied from 0.8 to 1.5 parts per 1,000. It has been in exceptional cases as low as 0.3 and as high as 4.00 parts per 1,000.

The temperature in ordinary working conditions varied from 50° to 75° F., and when grouting extensively in the rock sections it varied from 80° to 110° F.

Careful records were kept of information which might lead to the acquisition of further knowledge on the question of compressed-air sickness. The following are some of the conclusions to which a general study of the records and diagrams kept appear to lead, although these conclusions are only put forward tentatively and are not to be taken as applicable to other cases where conditions such as pressure, ground, temperatures, etc., might be different:

(a) When the air pressure was increased, even only to the extent of two or three pounds per square inch, after a steady period of work at a constant lower pressure, there was an epidemic of "bends" within about 48 hrs. after the raising of the pressure, followed by a return to the normal number of cases. This increased trouble occurred in some cases when the air was unusually pure with a large escape at the shield.

(b) The length of stay in compressed air has a direct influence on the chance of becoming affected; the longer the stay the greater the chance of being attacked.

(c) The rate of decompression has a direct influence on the chance of becoming affected; the slower the rate of decompression, the greater likelihood of escape. This was borne out by the fact that whenever two locks were in use, necessitating decompression in two stages, with a walk between the stages, the number of cases treated was always lower than when only one lock was in use, other conditions being similar.

(d) Provided that the average percentage of CO_2 gas is kept within about one part per 1,000, temporary variations between 0.4 per 1,000 and 1.5 per 1,000 do not seem to have any bearing on the cases of "bends."

(e) A supply of 3,000 cu. ft. of free air per man per hour, for pressures from 25 to 30 lbs. per sq. in., seems to be sufficient, and temporary variations of a 1,000 cu. ft. of free air per man per hour, above and below this figure, do not seem to affect the number of cases of "bends."

(f) There are a certain number of men who are naturally and constitutionally unfit for compressed air work under any conditions, and this unfitness is not always apparent at the time of medical examination.

(g) Under similar conditions of pressure, etc., more cases appear to occur when the temperature of the outside air is low than in warm weather.

As was earlier stated, the contract for the construction of these tunnels was let to the O'Rourke Engineering Construction Co., of New York, of which Messrs. John F. O'Rourke and F. J. Gubelman are respectively President and Vice-President. Their general superintendent in charge of construction is Mr. George B. Fry, who was assisted by Mr. J. F. Sullivan, Assistant Superintendent, and Mr. Patrick Fitzgerald, Tunnel Superintendent. The field organization of the contractor is shown in diagram herewith.

This work, as also the other portions of the Pennsylvania R. R. New York terminal work, is under the administration of Mr. Samuel Rea, Vice-President of the Railroad Company. The design and the supervision of construction is in the hands of Mr. Charles M. Jacobs, Chief Engineer. Pertaining to this work, as well as to all the other tunnel and terminal work of the Pennsylvania Railroad, there is a Board of Consulting Engineers to whom are submitted for approval the leading features of the work. This Board of Engineers is composed as follows: Brig.-Gen. C. W. Raymond, Chairman; A. Noble, Chief Engineer East River Division; George Gibbs, Chief Engineer Electric Traction; William H. Brown, Chief Engineer Pennsylvania Railroad; Charles M. Jacobs, Chief Engineer of this work.

The engineering staff organization established for the conduct of the work is represented by the diagram herewith. Mr. B. H. M. Hewett is General Resident Engineer of these Subaqueous tunnels; the Resident Engineer of the New York section is Mr. William L. Brown; of the New Jersey section Mr. H. F. D. Burke. The Resident Engineers of the Terminal Station West and the Bergen Hill tunnels, now in active progress, but not here described, are Messrs. B. F. Cresson, Jr., and F. Lavis, respectively; the former acted as Alinement Engineer until commencement of construction work. Mr. Paul Seurot and Mr. J. Soderberg are Office Engineer and Mechanical Engineer, respectively. The Chief Medical Officer is Dr. A. J. Loomis. The writer, as Chief Assistant Engineer to Mr. Jacobs, is in direct charge of the work.

It has been suggested to the writer that a comparative statement giving particulars of some of the principal tunnels constructed under waterways, many of which have been considered impracticable until made possible by the shield system (the nucleus of which was originally conceived by Brunel) so well developed in practice by Barlow and Greathead. Two statements are given, Tables VI. and VII., one embracing tunnels to carry railroad traffic and the other showing tunnels for purposes other than this. It should be noted that the subaqueous work given in these tables and accomplished without the aid of a shield was in most cases accompanied by much loss of life and destruction to the work. There is one case, however, where there was serious loss of life in a tunnel constructed by shield at Melbourne, Australia, in 1895, when seven men were drowned in the heading. In this case the shield used was entirely unsuited for the purpose.

THE TELHARMONIC SYSTEM OF PRODUCING MUSIC ELECTRICALLY.

In the office building at the corner of 39th St. and Broadway, New York City, within a stone's throw of the Metropolitan Opera House, the center of high-class musical art in America, is now located a new musical industry—new in the sense that the music is produced and distributed by electricity without the use of any musical instrument, and that the plant has been in operation for only a few months.

The Telharmonium is the name of the new music-producing apparatus. It has nothing in common with any other musical device or instrument, but is purely an electrical machine by whose operation a musician may produce any music known to the human ear. The sounds are produced by telephone receivers provided with horns of the megaphone type, several of which are located in the concert room at 39th St. and Broadway, where daily musical performances are given, and others are installed in prominent hotels from 23d St. to 45th St. along Broadway and Fifth Ave. The music issuing from the horns is sufficiently powerful to fill an ordinary room, being about the same in loudness as that from a violin or piano, and the horn from which it issues may, if desired, be entirely concealed from view.

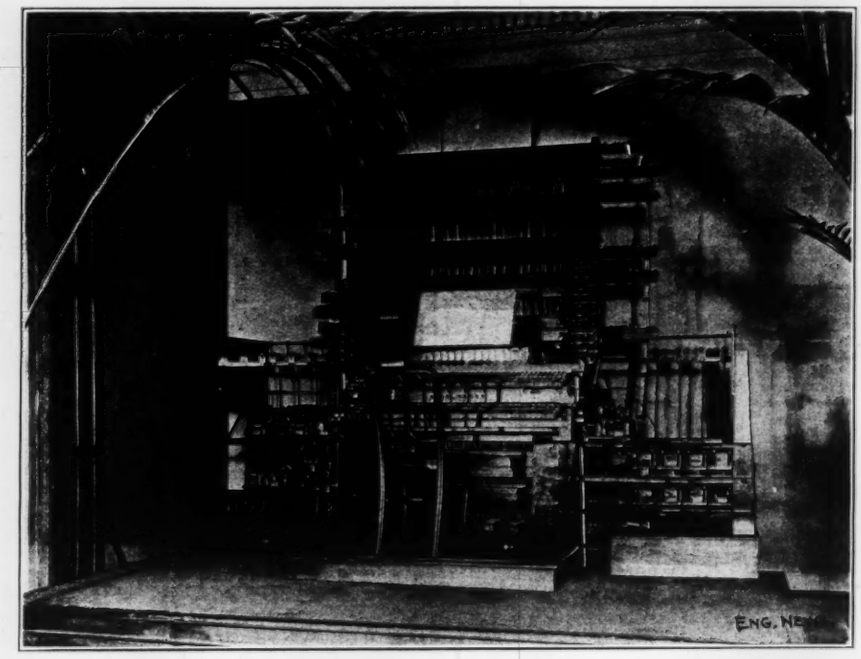


FIG. 1. KEYBOARD OF THE TELHARMONIC SYSTEM FOR THE PRODUCTION OF MUSIC BY ELECTRICITY.

With the exception of the keyboard, Fig. 1, which is located in the concert hall previously referred to, the apparatus of the plant is in the basement. Here is a series of 144 electric alternators, each giving a current of a certain frequency. When these currents are sent into a telephone receiver they cause the diaphragm to give out a musical note of a pitch corresponding to the number of alternations. When the musician presses down a key on the keyboard, a magnetic circuit is closed on the switchboard, Fig. 2, which causes a rod to be lifted and the currents from one or more alternators to be sent over the wire. Before passing out to the distributing lines, however, these currents are tempered and blended by the tone mixers shown in the lower part of Fig. 2.

The alternators are driven by a 185-HP. constant speed direct-current motor. They are of the inductor type, the revolving portion of each consisting of an iron rotor with pole pieces corresponding in number to the frequency desired for each particular machine. The range of frequencies thus obtained from the 144 alternators is from 40 to 4,000 cycles per second. By depressing any certain key on the keyboard there results a current in the telephone receivers which causes their diaphragms to vibrate so as to correspond in frequency to the ground tone of the desired musical note and the various par-

tials or overtones, the loudness of the latter being under the control of the musician.

There are two keyboards equipped with 144 keys each, enabling two musicians to play simultaneously, and together to have control over 20 keys at any one time. These keys, however, do not act directly upon the circuits from the alternators, but actuate plunger magnets which, in turn, control these circuits. Each magnet when actuated draws up a strip of wood which carries a set of fingers serving to actuate the switches corresponding to the ground tone and overtones of the desired note.

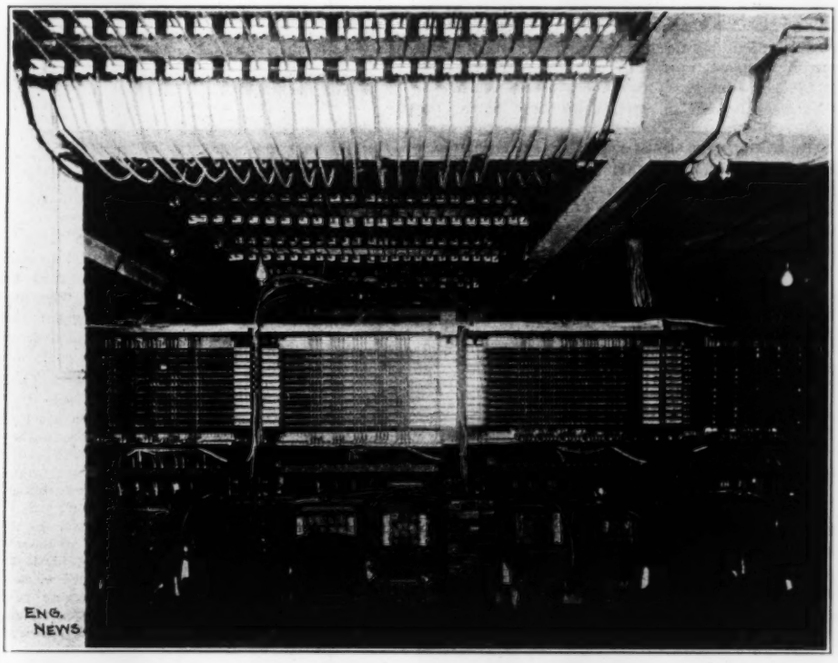


FIG. 2. PART OF THE SWITCHBOARD AND TONE MIXERS OF THE TELHARMONIC SYSTEM.

The bus bars on the switchboard are so arranged that the currents producing the ground tones are superposed in one circuit and the currents for each of the overtones are superposed in separate circuits. The currents in these circuits pass through the primaries of closed iron magnetic circuit transformers, and in the secondaries of these transformers are impedance rheostats controlled by the musician for varying the strengths of the currents. The secondary currents are next led through the primary winding of an open ironwork magnetic circuit transformer, the secondary current from which passed through the primary of an air-core transformer, and the secondary current from this actuates the various receivers.

The reasons for using three transformers instead of one are the elimination of annoying overtones which otherwise assert themselves and the greater opportunity afforded of controlling the values of the different factors entering into the final result.

The telharmonic system is a wonder both to the layman and the professional engineer: to the latter on account of the complexity of the circuits and their operation, and to the former by reason of the degree of perfection attained in this, the first plant of its kind, during a period of little over two years by one man—Dr. Thaddeus Cahill—its inventor and promoter.

Regarding the present size and future possibilities of the system, it may be stated that distributing cables have been laid along Broadway, from 23d St. to 45th St., and along Fifth Ave., from 23d St. to 34th St., and connections have been made with a number of hotels, restaurants and residences in that section of the city. The station at present has enough power to supply about 10,000 outlets simultaneously. Two additional keyboards and a number of expression devices are now being constructed in Dr. Cahill's laboratory at Holyoke, Mass., and these will be installed in the station at 39th St. and Broadway as soon as completed.

The quality of the new music is surprisingly good; the tones now produced are intended to be reproductions of the wood-wind instruments—the flute, oboe, etc., but with a range from the highest to the lowest on the scale.

The aim of the new invention is not only to produce a high quality of musical sound but to effect the distribution of music on a large scale. It is claimed that with a properly equipped central station, the Telharmonic music could be distributed to all the residences within a radius of 150 miles of New York City. A half dozen operators at the keyboards could duplicate the effect of an orchestra of 150 pieces, and an audience of a million people could listen at once to the resulting music.

THE EXPERIMENTAL SEWAGE TREATMENT WORKS FOR BALTIMORE, MD.

An experimental sewage treatment plant is now being installed at Baltimore, Md., to gain information for use in designing the proposed sewage works for the whole city. One of the chief objects of the experimental plant is to determine whether or not intermittent sand filters are necessary as a finishing process after the sewage has been treated in succession by septic tanks, sprinkling or percolating filters and small settling basins. The reason for considering this matter is stated below. The most notable features of the experimental plant are the sprinklers for the percolating filters, including the spraying devices and the method of driving the sprinklers; also the varying depths and character of filtering material and the continuous underdrainage system to be employed.

Although Baltimore now has a population of nearly 600,000, it is still without a sewerage system for the removal of household wastes. One cause for delaying the introduction of sewers so long has been the fact that the discharge of sewage into Chesapeake Bay would seriously injure the large oyster industry carried on there. To guard against this danger the Enabling Act, passed two or three years ago, authorizing the city to issue $10,000,000 bonds for sewerage and sewage disposal purposes, prohibited the discharge of domestic or sanitary sewage into Chesapeake Bay or any of its tributaries. This prohibition was interpreted by the Baltimore Sewerage Commission to mean that the effluent from sewage works must "be of the highest standard of purity." Accordingly the board of advisory engineers, in its report on a plan of sewage treatment,* recommended the unusually elaborate combination of methods mentioned above, namely, septic tanks, percolating filters, settling basins and intermittent filters. The plan recommended by the advisory engineers contemplated a separate system of sewerage with pumping and sewage treatment works of sufficient size to treat 75,000,000 gals. per day. The effluent from the works would be discharged into Back River, an arm of Chesapeake Bay. The advisory engineers were of the opinion that the effluent from the percolating filter without further treatment would neither endanger the oyster beds in the bay nor cause offence along the shores. Mr. Calvin W. Hendrick, M. Am. Soc. C. E., Chief Engineer of

*See Eng. News, Aug. 16, 1906, for an abstract of the report. The advisory engineers included Messrs. Rudolph Hering, Samuel M. Gray and Frederic P. Stearns, M.'s Am. Soc. C. E.

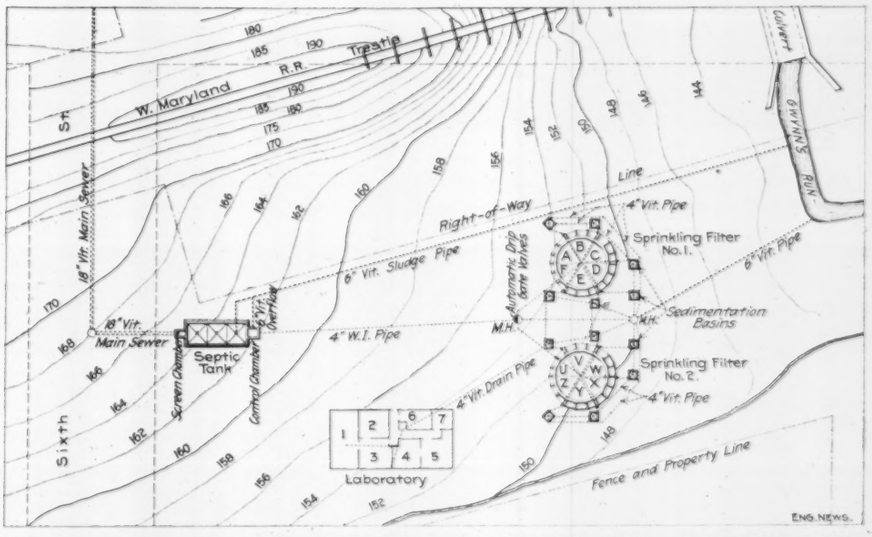


FIG. 1. GENERAL PLAN OF EXPERIMENTAL SEWAGE TREATMENT WORKS, BALTIMORE, MD.

Laboratory Building.	Depths of Various Beds of Sprinkling Filters.		
	No. 1.	No. 2.	Depth, ft.
1. Chemical Laboratory	Bed A.	U.	6
2. Bacterial Laboratory	Bed B.	V.	9
3. Preparation Room	Bed C.	W.	12
4. Cement Laboratory	Bed D.	X.	12
5. Mechanical Laboratory	Bed E.	Y.	9
6. Store Room	Bed F.	Z.	6
7. Office			

the Baltimore Sewerage Commission, in a report supplementary to that of the advisory engineers, stated that he had investigated the location of oyster beds in Chesapeake Bay in relation to the proposed works, and found that the nearest point at which oysters were cultivated was 14 miles distant from the outlet of the sewage works. He considered the chance of pollution of these beds only a remote possibility and advocated the installation of an experimental plant to determine what degree of purification could be secured without intermittent filters. The importance of such tests may be better appreciated when it is stated that the estimated construction cost of the works without intermittent filters would be $2,242,500, and that the intermittent filters would add $1,041,000 to the above sum. As neither of these figures included the cost of land, it will be seen that the cost of intermittent filters would really add considerably to the necessary outlay. The operating expenses of the plant without intermittent filtration were estimated at $60,500 a year, and with filtration at $55,000 additional, which, if capitalized, would add over a million, thus making a possible saving of over $2,000,000.

Through the courtesy of Mr. Hendricks we are enabled to present herewith detailed plans of the experimental sewage treatment plant. The experimental plant includes substantially all the elements proposed in the plan recommended by the advisory engineers, with the exception of the intermittent filters. The septic tank is 10 × 30 ft. in plan and has an effective depth of about 8 ft. There are two circular sprinkling filters with a gross diameter of 26 ft., each filter being divided into six compartments or beds; two of the beds are 6 ft., two 9 ft. and two 12 ft. in depth. Adjacent to each bed is a small settling basin about 4 ft. square and between 2 and 3 ft. deep. A complete laboratory and office building is provided. The general lay-out of the experimental plant is shown by Fig. 1. The details of the septic tanks and also of the filter beds, except for the sprinkler arms, are shown by Fig. 2, while Fig. 3 presents in considerable detail the sprinkler arms and their driving mechanism.

A study of the illustrations will give a comprehensive idea of the various features of the experimental plant. It will be noted that an 18-in. sewer (from a district which is being sewered especially for the purpose of providing 50,000 gals. of sewage for the experiments) terminates in a grit or detritus chamber from which the septic tank will be filled. At the other end of the septic tank there is a control chamber provided with an adjustable weir. The incoming sewage will pass through two movable screens having meshes of variable size.

In place of the usual vertical spraying nozzles, often formed merely by holes in the top of the sprinkling arms, horizontal nozzles will here discharge the sewage on flat brass plates resting in a horizontal position, and from these plates the sewage will fall upon the beds.

One of the sets of filter beds has its sprinkler arm driven by an electric motor located in a chamber in the center of the filter; while the other set of beds makes use of a motor attached to the outer end of the sprinkler arm and running on a circular track (Fig. 3). Each plan requires some sacrifice of filtering area, but in the small-size bed this sacrifice will be small in proportion to the total area; in fact, for the end-driven sprinkler arm there would be no waste of space over that required in any event for feeding the sprinkler arm.

The filtering material will be composed of different combinations of ½ to 2-in., 1½ to 3-in., 2½ to 4-in. and 4 to 6-in. broken stone. Tests will be made of each size and of combinations of fine and coarse materials.

Attention may be called to the underdrainage system of the sprinkling or percolating filters. This is in effect a continuous false floor, formed of half tile cut on their supporting edges to admit the effluent. The outer end of each line of tile is provided with a socket (see Fig. 3).

The contracts for this experimental plant were awarded Oct. 10, 1906. The contractor for the laboratory building is Mr. William Kirkpatrick, of Baltimore, Md., whose bid was $3,750. The Malcolm W. Hill Co., 405 Cortland St., Baltimore, received the contract for the remaining portion of the plant, the contract price being $6,930 and the time specified for completing the contract 120 days. The detailed bids for the experimental plant are given below, in view of the interest attached to some of the items:

Quantity.		Rate.	Price.
825	cu. yds. earth excavation	$1.51	$1,245.75
50	" rock excavation	6.00	300.00
165	" concrete masonry, Class "A," 1 : 2½ : 5	8.90	1,468.50
10	" concrete masonry, Class "B," 1 : 3 : 7	7.90	79.00
1,368	lbs. steel reinforcement	.04	54.72
500	lin. ft. 4-in. Vit. sewer pipe	.12	60.00
125	lin. ft. 6-in. Vit. sewer pipe	.15	18.75
3	6-in. cast-iron seat valves	55.25	165.75
12	4-in. cast-iron seat valves	15.50	186.00
1,200	lin. ft. 6-in. lateral collectors	.15	180.00
1	adjustable weir	25.00	25.00
710	cu. yds. broken stone filtering material	2.43	1,725.30
130	cu. yds. rubble	2.19	284.70
5	" brick masonry	12.90	64.50
200	ft. B. M. lumber left in place	55.00	11.00
150	lin. ft. 4-in. w.-i. pipe, with fit'gs.	.49	73.50
Special machinery, including sprinkling-arm, track, etc.		895.00	895.00
Sewage screens		30.00	30.00
2	automatic drip gate-valves, with wheels	29.00	58.00
1½	-in. stopcock	5.00	5.00
Total amount of bid			$6,930.47

It is expected that the plant will be completed and put in operation about June, and that it will be run for some six months. The outcome of the tests will be awaited with great interest. Mr. E. B. Whitman is division engineer in charge

A LOBNITZ ROCK BREAKER for excavating rock under water has been installed by the Empire Engineering Corporation of New York City on a contract for the improvement of Black Rock Harbor, Buffalo, involving the excavation of about 260,000 yds. of rock under water at depths of 18 to 25 ft. The contractor's bid for this work was $1.85 per cu. yd. The rock cutter to be used was designed by Mr. F. W. Allan, Engineer for the Empire Corporation, and consists of a steel cylinder 28 ins. diameter, about 25 ft. long and weighing 46,000 lbs. At its lower end it is fitted with a hardened steel cutting point resembling that of an armor-piercing projectile. This weight is hoisted by a powerful steam winch, built by the Lobnitz Co., of Renfrew, Scotland, and is let fall upon the rock bottom from a height of 6 ft. or more. The hull on which the rock breaker and its operating machinery is mounted is held in position by six ¾-in. anchor cables, leading over bow and stern and to port and starboard from each corner. The ends of these cables lead to a Mundy six-drum hoisting engine so that the hull can be quickly shifted in any direction to deliver the blows at any desired point.

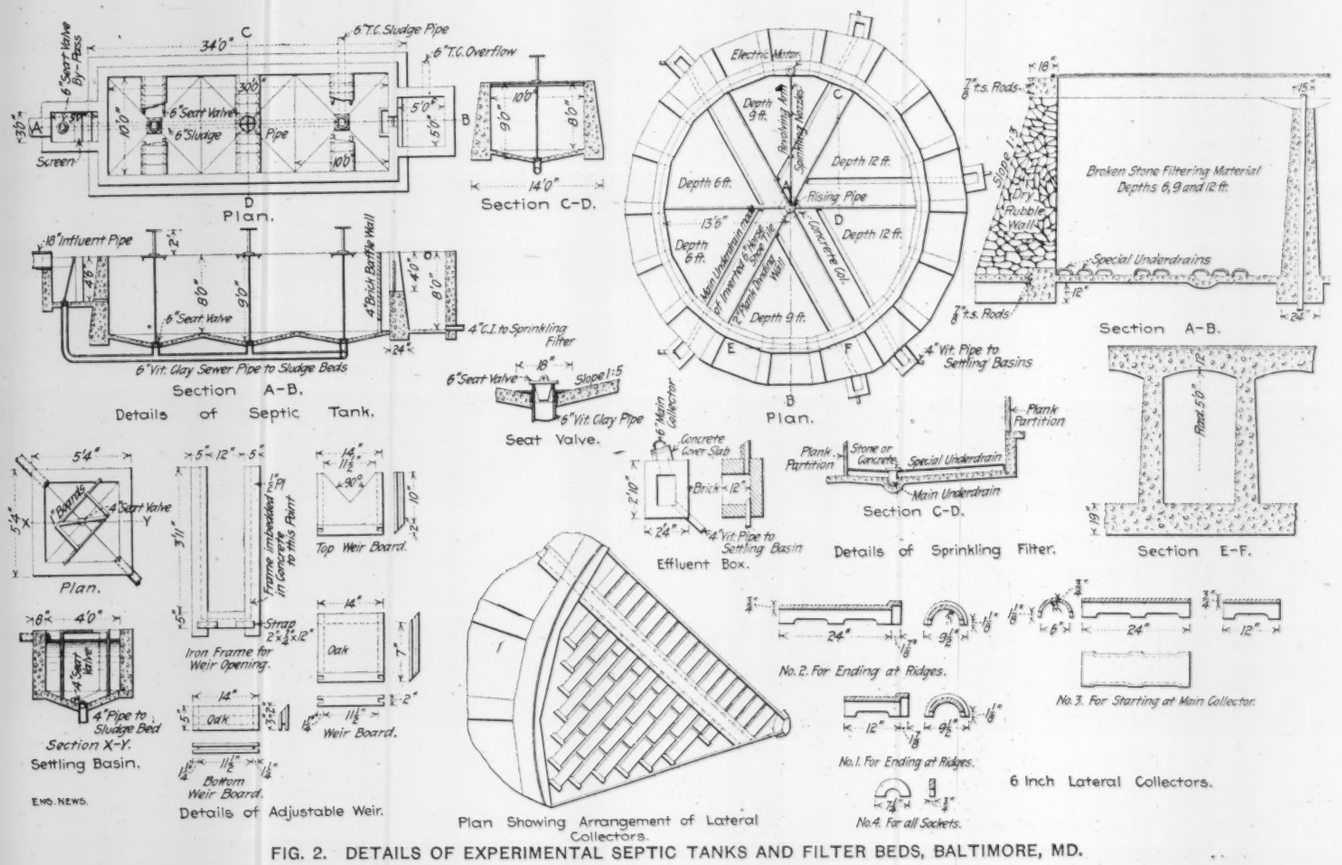
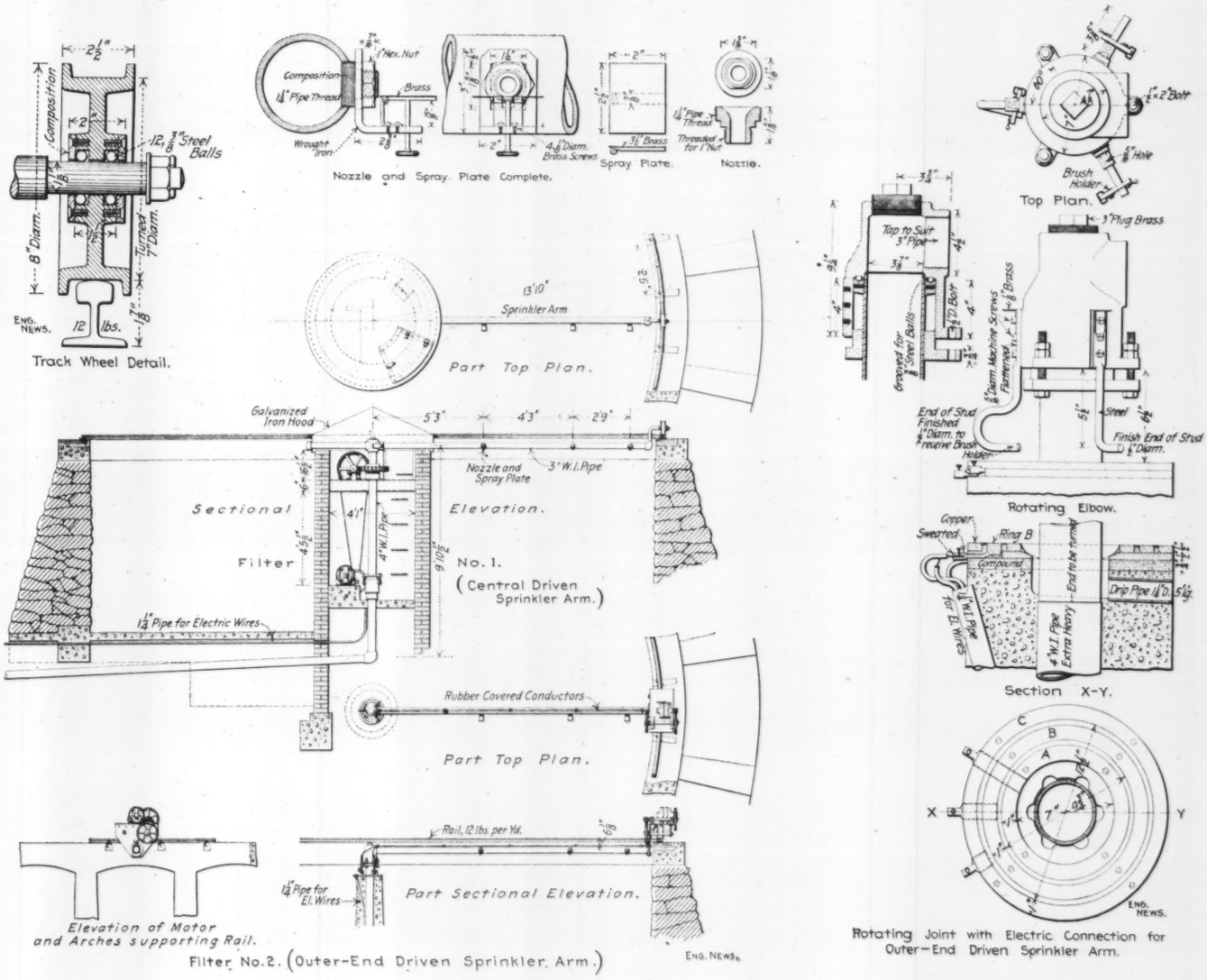


FIG. 2. DETAILS OF EXPERIMENTAL SEPTIC TANKS AND FILTER BEDS, BALTIMORE, MD.



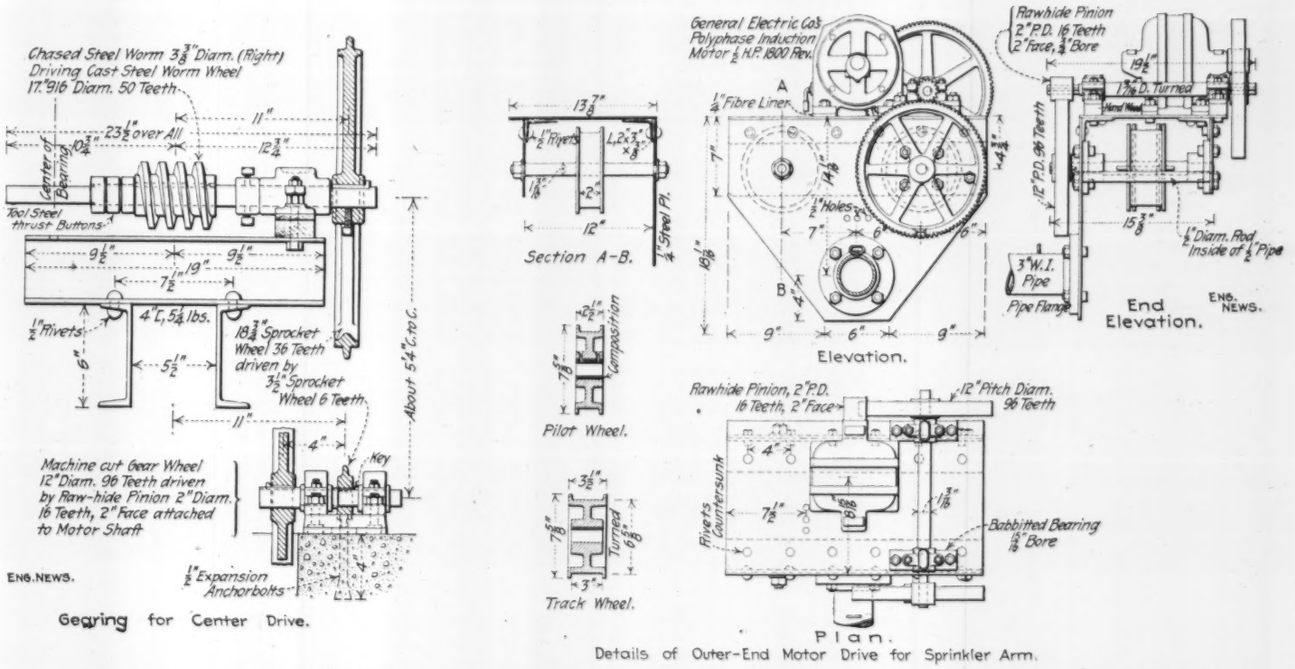


FIG. 3. DETAILS OF CENTRAL AND OUTER END ELECTRIC MOTOR DRIVEN SPRINKLER ARMS FOR EXPERIMENTAL SEWAGE FILTERS, BALTIMORE, MD.

THE MUNICIPAL SEWAGE EXPERIMENT STATION, OF WATERBURY, CONN.

By WM. GAVIN TAYLOR.*

The sewage purification problem of Waterbury, a city of 65,000 population, situated in central-western Connecticut, has been one of ever increasing importance. The expense and difficulties involved in the solution of the problem have materially delayed the execution of the requisite works and the abatement of the continued pollution of the several water courses.

The city is located within the valley of the Naugatuck River, 30 miles above Long Island Sound. Throughout its length the valley is narrow and the hills on each side are bold and rocky, rising in many places abruptly from the river bank, forming precipitous cliffs. Wherever a widening in the valley occurs a manufacturing city, town or village has been developed. Tributary to the Naugatuck River at Waterbury is a rough and hilly drainage area of 214 sq. miles. The river gradient is steep As a result of these topographical conditions the river flow is extremely variant, responding quickly to storm conditions. The stream flow ranges from a minimum of about 40 cu. ft. to a maximum of more than 10,000 cu. ft. per sec. Throughout the larger portion of the year the dilution obtainable for the sewage flow is entirely inadequate for the prevention of putrefaction. During periods of low summer flow the dilution is not greater than two parts river water to one part sewage.

*Resident Engineer, Sewage Disposal Works, Waterbury, Conn.

Although the city is within the limits of the sand and gravelly deposits of the glacial drift which have made the intermittent sand filtration system of sewage purification possible as the standard New England method, no tract of land of suitable character and of sufficient area for the filtration of the sewage of Waterbury by that method is to be found in the valley within a distance of 20 miles.

To reach a sand filtration field outside the Naugatuck valley would require the construction of long and expensive tunnels or the pumping of the sewage over the summit of the easterly range and the construction of a long trunk line down the easterly slope. The cost of such works would be an extraordinary burden upon the city and one which it could not well carry in addition to the payment of damages which, without doubt, would be exacted by lower riparian owners for the diversion of waters now tributary to the river and used in the several water privileges.

To construct a trunk sewer to Long Island Sound is not practicable, inasmuch as the geological conditions and the topography of the 30 miles of valley between Waterbury and tidewater are such as to make the cost prohibitive to a city of 65,000 inhabitants. There is, moreover, no doubt that the discharge of a large volume of crude sewage near the shore would be immediately enjoined, owing both to its contaminating effect upon the shell-fish and its offensiveness to residents along the shore.

These adverse conditions made it highly desirable for the city to find ways and means, if possible, whereby the purification of the sewage might be effected at high rates upon a comparatively small tract of land having characteristics such as could be obtained in the valley below the city and within a few miles. No method of sewage treatment, regularly in use in the United States, offered such advantages as to cost of construction and maintenance, the obtainment of high working rates and consequently the possibility of the use of small areas, as did the system of purification by percolating filters, recently developed in England. The adaptability of continuous filters, upon which the sewage is applied in the form of a spray, was untried for the purification of the sewage of an American city under New England climatic conditions. The winters in Connecticut are very much more severe than those experienced in England, and this fact, it was thought, might render impossible the successful operation of uncovered sprinkling filters.

The long series of tests made at Lawrence, Mass., upon percolating filters has been invaluable in the advancement of the world's knowledge of sewage purification, yet the Lawrence studies upon this type of filter have been upon a small scale and under conditions widely varying from those governing the operation of sewage works at Waterbury. Contemporary with the investigations at Waterbury, about to be described, an elaborate series of tests was being made by the city of Columbus, O. The character of the Columbus sewage is very different from that of Waterbury, and many of the local conditions vary widely.

These and other points of difference between the problems already solved and those met with

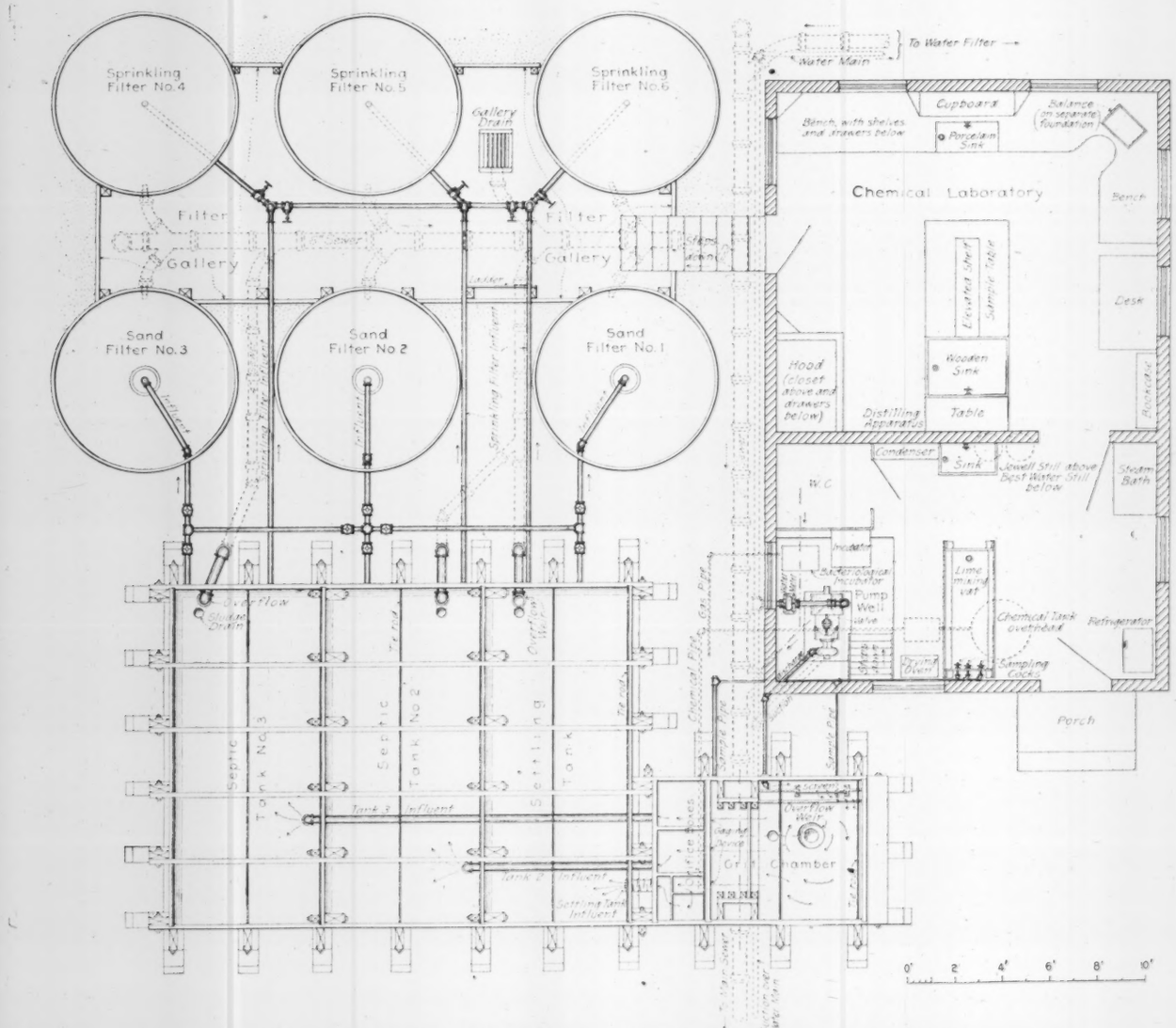


FIG. 1. GENERAL PLAN OF SEWAGE EXPERIMENT STATION, WATERBURY, CONN.

in Waterbury made it of vital importance that a series of local tests be made. The principal conditions necessitating the tests may be stated as follows:

(1) Absence of definite knowledge concerning the character of Waterbury sewage.

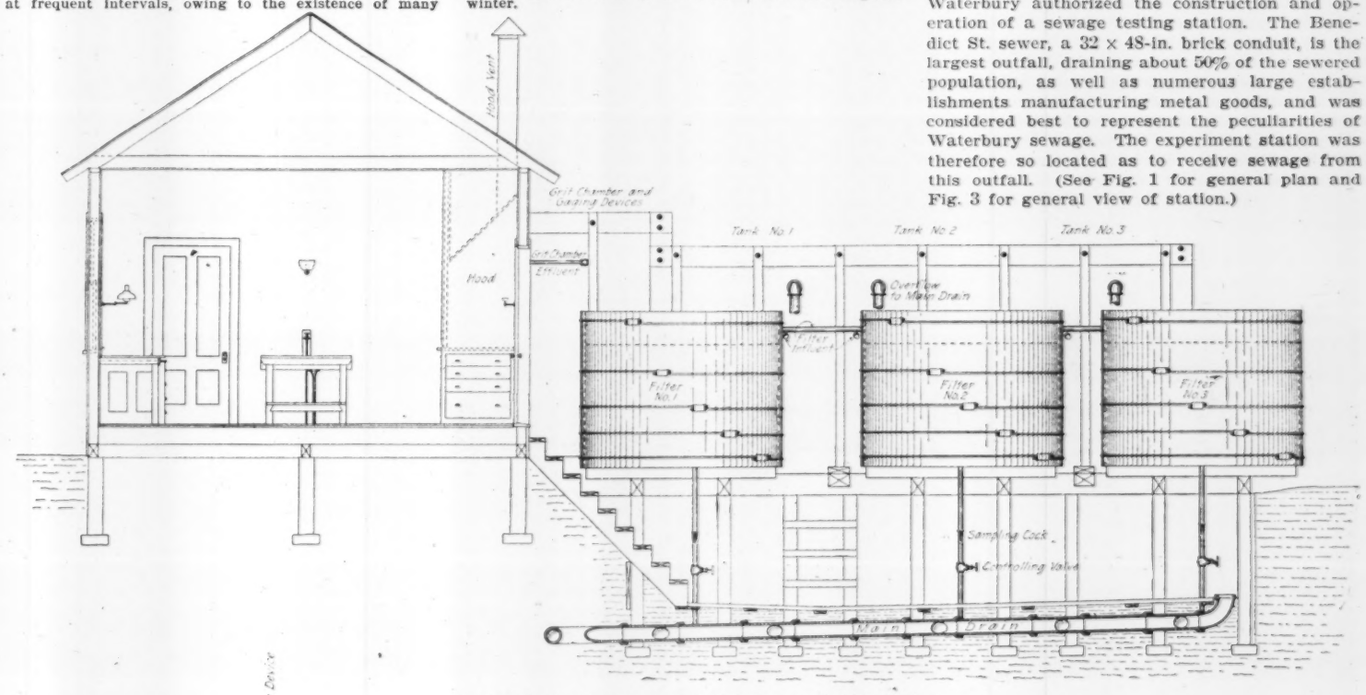
(2) Local belief that the sewage was strongly acid, at frequent intervals, owing to the existence of many manufacturing concerns using acid "pickles" for the removal of oxides from copper, brass and other metallic products.

(3) Lack of knowledge concerning the applicability of high-rate sprinkling filters to the purification of sewage from American manufacturing cities—there having been no regular installations of this type of filter in America.

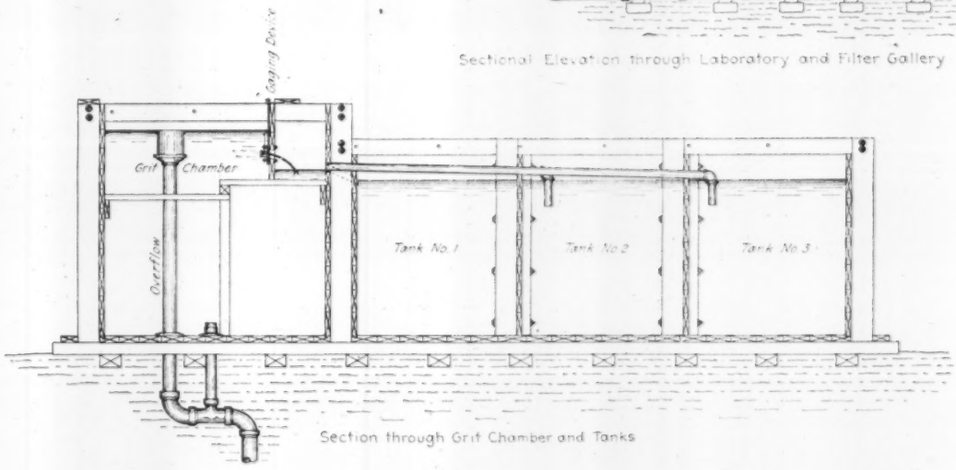
(4) Unknown behavior of sprinkling filters during the long period of low temperature found in a New England winter.

(5) The great importance to the City of Waterbury of the procurement of a method whereby it would be possible to effect a purification of its sewage at high rates, at an economic cost, upon available land favorably situated with respect to natural drainage and density of population, and so located as to avoid the diversion of waters now used for power.

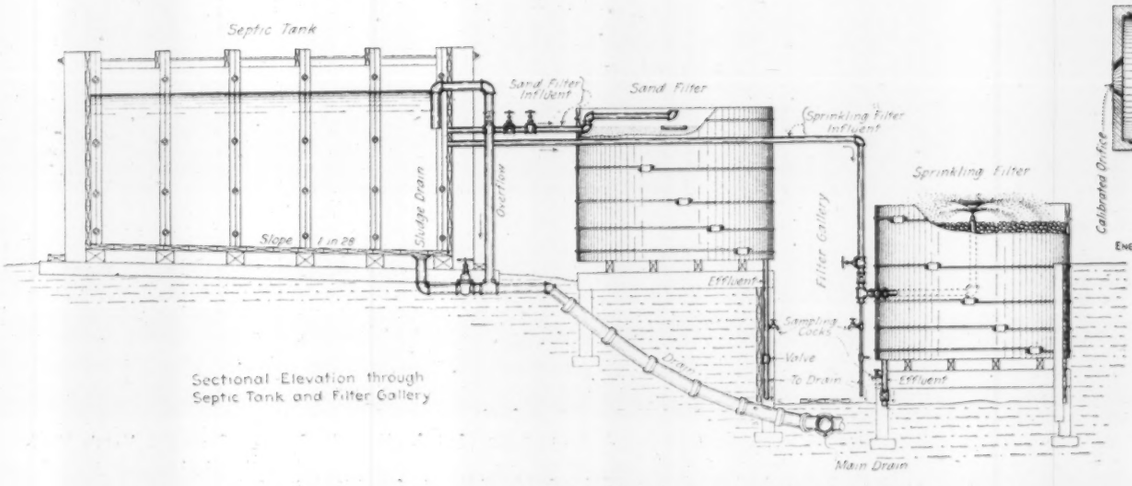
Early in 1905 the Board of Public Works of Waterbury authorized the construction and operation of a sewage testing station. The Benedict St. sewer, a 32 × 48-in. brick conduit, is the largest outfall, draining about 50% of the sewered population, as well as numerous large establishments manufacturing metal goods, and was considered best to represent the peculiarities of Waterbury sewage. The experiment station was therefore so located as to receive sewage from this outfall. (See Fig. 1 for general plan and Fig. 3 for general view of station.)



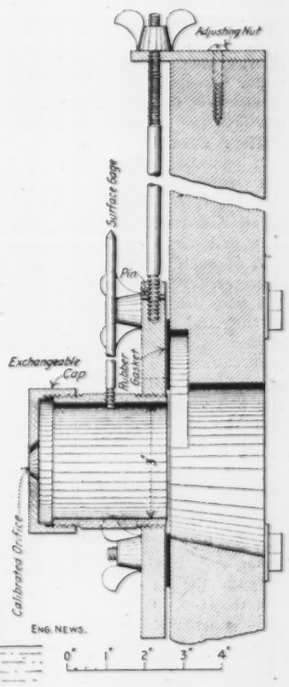
Sectional Elevation through Laboratory and Filter Gallery



Section through Grit Chamber and Tanks



Sectional Elevation through Septic Tank and Filter Gallery



Gaging Device.

FIG. 2. DETAILS OF TANKS AND FILTERS, SEWAGE EXPERIMENT STATION, WATERBURY, CONN.

SEWER CONNECTION.—A temporary manhole, 5.5 x 7.5 ft., was constructed from the street to the extrados of the sewer arch. Through the sewer arch two openings were made, one to permit the entrance of the pump suction and foot valve and one to receive the sewer draining the station. The following connections were also made for the particular use of the station: A 6-in. sewer, a 2½-in. water service, a 2½-in. sewage

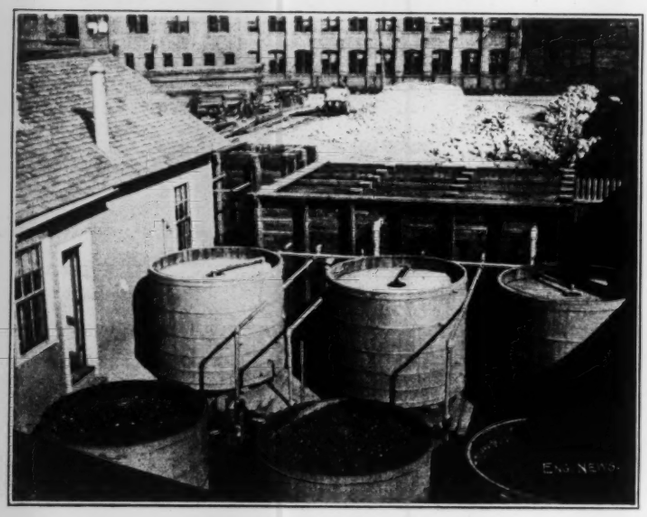


Fig. 3. General View.

Fig. 4. Sand Filter No. 1, Ridged for Winter.

FIGS. 3 AND 4. VIEWS OF SEWAGE EXPERIMENT STATION, WATERBURY, CONN.

suction and a 1¼-in. gas service. The foot valve was placed so as to draw from the mid-depth of the ordinary sewage stream.

PUMPING EQUIPMENT.—Within the laboratory building, in a well 5.5 ft. below the laboratory floor, there was placed a 1½-in. Lawrence centrifugal pump. The pump is directly connected to a 12-in. Pelton wheel, which is driven by water from the city mains discharging through a ¼-in. nozzle under a pressure of 105 lbs. per sq. in. The static lift of the pump is 13.7 ft. on the suction side and 9.7 ft. on the discharge side. Under normal conditions the impeller wheel is driven at about 950 r. p. m. and discharges 46.5 gals. of crude sewage per minute into the grit chamber.

GRIT CHAMBER.—Sewage upon entering the grit chamber passes through a wire screen for the purpose of removing the coarser floating matter, which if not intercepted would tend, possibly, to influence the accuracy of the gaging devices. The grit chamber is nearly square, 2 ft. deep, and of such capacity that the flow period is ten minutes. Within the grit chamber is deposited the very heavy suspended matters and the bulk of the sand and road detritus entering the sewers through the street inlets. Near the center of the grit chamber a circular overflow weir has been provided to maintain the surface of the sewage in the grit chamber at a constant level and to permit the wasting of such sewage as might be pumped in excess of that used in the tests.

Bolted to the wall of the grit chamber adjacent to the rectangular tanks are three gaging devices (Fig. 2), each consisting of an iron plate bored to receive a 3-in. brass pipe nipple; over the end of the nipple is screwed an exchangeable brass cap, having at its center a circular orifice to gage the flow of the sewage passing through. To the top of the nipple is affixed a surface pointer having its point exactly 12 ins. above the center of the sharp-edged gaging orifice. By means of a thumb screw the whole device may be raised or lowered to compensate for a change in the rate of pumping, and also to provide a convenient mode of adjusting the orifice. A number of interchangeable orifice caps were made and accurately calibrated so that the flow-periods of the three rectangular tanks, used for the preparatory treatment of the sewage, might be almost instantly controlled.

PREPARATORY TREATMENT TANKS.—Three rectangular tanks were constructed for the preparatory treatment of the effluent of the grit chamber. Tank 1 was designed for continuous use either as a chemical precipitation or as a plain sedimentation basin. The sewage enters through a baffled fishway and the supernatant fluid is drawn off for filtering or allowed to waste over a circular weir. Tanks 2 and 3 were designed for septic action. The inlet and outlet connections are submerged (see Fig. 2) for the purpose of maintaining the continuity of the surface scum. These tanks have the following general dimensions: Length, 14 ft.; width, 6 ft. 1 in.; mean depth, 6 ft. 3 ins. The capacity of each is 4,000 gals.

Yellow pine was used in the construction of the tanks, the bottom and sides being of 2½-in. planks, supported upon two courses of 8 x 10-in. timbers and braced by 5 x 12-in. verticals. These verticals are mortised into the supporting timbers at the base and are kept from spreading at the top by ¾-in. round iron rods. Water tightness was secured by milling the edges of the side and bottom planks to form a tapered joint, which was subsequently calked with cotton wicking and pitch.

Sewage is drawn from each of the three tanks to the sand and sprinkling filters through two systems of feeders. Each feeder consists of a 2-in. galvanized iron pipe with controlling valves and is connected into the tank at the end opposite the influent stream. These tank effluent pipes are cross-connected and so controlled by valves that the effluent from any tank may be discharged to either one, two or three of either set of filters, as may be desired.

The tank floors are laid to a slope of 1 in 28 to facilitate sludge drainage. At the lower end of each tank there is a 4-in. waste, leading to the sewer, through which the tank may be completely drained.

SAND FILTERS.—Three sand filters, each having a net area of 0.001-acre, were constructed within water-tight cypress tanks, 7 ft. 5⅜ ins. in diameter. Each filter is supported by chime joists, resting upon a timber foundation. The filtering material is medium coarse clean bank sand, having an effective size of 0.24 mm., and a uniformity coefficient of 2.75.

The sand filters are not underdrained, but the floors are sloped toward the 4-in. outlet pipe, about which was placed a small cone of graded gravel to prevent the escape of the filtering material. Upon each outlet pipe is a gate valve, which may be operated in connection with a hose bibb, placed immediately above, for the collection of samples.

The influent to the sand filters is discharged into a cement basin, 12 ins. in diameter and 2 ins. deep, the rim of which is flush with the sand surface (Fig. 2). The flooding sewage fills the basin, flows over its rim and across the entire surface of the sand bed without in the least disturbing the surface layer. After flooding, the sewage left in the basin drains through a small hole in its bottom.

CONTACT BED.—One contact filter has been tested to show the efficiencies obtainable with the local sewage. Single contact, only, is provided and the rate of filtration is controlled by changing the number of fillings per day. The contact filter, constructed within the cypress tank first used for sand filter No. 2, has as a contact material crusher run broken trap rock ranging in size from a minimum diameter of ½-in. to a maximum diameter of 1¼-ins. The initial voids in the filtering material were 45%.

Septic sewage has been applied to the contact filter and provision made for the aeration of the influent stream as desired. Valves upon the influent feeder and the effluent waste were calibrated for the filling and draining of the bed

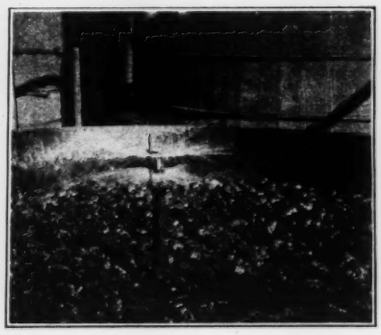


Fig. 5. Double Spray Nozzle Used on Filter No. 5.

Fig. 6. Umbrella Spray or Perconate Nozzle Used on Filter No. 6.

FIGS. 5 AND 6. NOZZLES USED ON EXPERIMENTAL SPRINKLING OR PERCOLATING FILTERS, WATERBURY, CONN.

at varying periods; normally each of these phases was of one hour's duration.

SPRINKLING FILTERS.—Arranged along the filter gallery (Fig. 1) and placed symmetrically with the sand filters are three sprinkling filters (Nos. 4, 5 and 6). Each filter is constructed within a cypress tank, similar to those described under sand filters, each having an effective area of 0.001-acre. The filling material consists of 4.5 ft. of broken trap rock, having diameters varying from 1¾ to 2¼-ins., placed above a stratum of 6-in. round cobbles. A cement floor, having a slope of 1 in 48, was constructed within each filter-tank and sloped toward the outlet to facilitate drainage. The surfaces of the sprinkling filters are 6 ft. below the flow line in the basins for preparatory treatment. This difference in elevation, minus a small friction head, represents the pressure upon the nozzles for the distribution of the influent stream. An influent pipe, at the center of each bed, rises through the broken stone. Just above the surface the influent riser is capped with a distributing nozzle. The applied sewage percolating through the broken stone is quickly drained to a 4-in. outlet and thence to the sewer. The outlet pipe has a gate valve and a hose bibb for the control of the filter and the collection of samples, respectively.

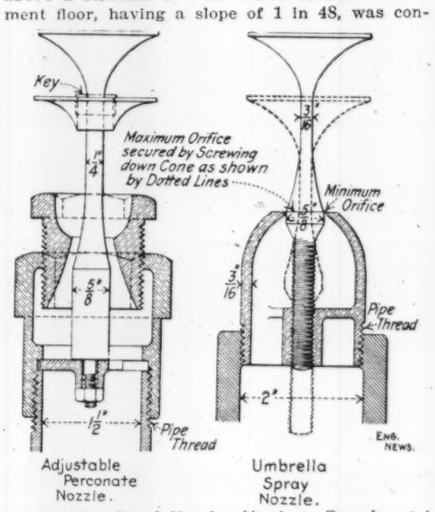


Fig. 7. Details of Nozzles Used on Experimental Sewage Filters, Waterbury, Conn.

Special sprinkling filter No. 5 is a remodelling of Filter 5. A partition was constructed vertically through the middle of the filter tank. One division was refilled to a depth of 5 ft. with the same material as that in the original filter. The other division was partitioned into four sections, each having a separate bottom; one section was refilled so as to have 4.5 ft. of filtering material, another 4 ft., a third 3.5 ft. and a fourth 2.5 ft. Each sector has an individual effluent drain, together with provisions for sampling. Similar filtering materials were used in each sector, and in fact each section is exactly alike except in one feature—that of depth.

This special filter was designed to show the effect of the varying depths of the filtering material and to make possible a detailed study of the purification effected in the filter at each successive stage. One fixed sprinkler nozzle, placed at the center of the bed, diffuses the applied sewage equally over all of the sectors.

SEWAGE DISTRIBUTORS.—Distribution of sewage over the surface of sprinkling filters is one of the most important features in the construction and operation of this type of sewage filter. Many tests have been made at this station of distributing devices, all of which have been of the fixed sprinkler head type and operated under a constant pressure, except, that in the more recent tests an undulation of the nozzle pressure has been an important feature.

Revolving and travelling distributors have not been tested locally, owing to the belief that the continuous operation and maintenance of such during the severe New England winters would be extremely difficult if not impracticable. In England, where revolving and travelling distributors have been extensively studied and applied not only to experimental filters, but also to large-sized beds, they have not been thoroughly satisfactory, as yet designed, and they are there growing in disfavor, being succeeded by fixed sprinkler heads. Under favorable climatic conditions revolving and travelling distributors can without doubt be designed for the satisfactory and economic distribution of sewage, although unfavorable conditions are likely to arise in particular cases. Such is the case at Waterbury, where the sewage favors the development of a luxuriant fungus growth, which would add materially to the cost of maintaining open waterways in the feeder arms or channels.

Distributing devices designed and tested at Waterbury have been only of such character as would lead up to the development of a nozzle head suitable for adoption upon the future working plant. The studies upon distributors are still in progress, and although excellent results have been obtained none of the devices have reached the ideal standard.

Avoidance of numerous small openings, through which the previously treated sewage must pass, was appreciated at the outset, and in all nozzle designs a single central orifice was an essential feature. This principle reduced to a minimum the liability of a partial or complete interruption of the influent stream by suspended matter or the closing of the area by fungus growths or other agents. Owing to the necessity for perfect protection of the feeding mains against frost action, the nozzles designed have been of what might be called the under-fed type, that is the feeding mains and nozzle supplies have been placed sufficiently below the surface of the filtering material to insure protection.

Many attempts have been made to affix an inverted cone externally over a central orifice, in a satisfactory manner; under local conditions, at least, it is believed to be impracticable. Simplicity, rigidity, continuity of spray and evenness of distribution have been difficult of attainment in nozzles having a cone so attached. Even when these conditions were well controlled, the radial continuity of the sewage spray was not constant, owing to the collection upon the blades of filamentous matter. Nozzles having a central spindle supporting an inverted cone or spreader were more satisfactory in operation, as well as more simple in construction and less expensive.

Evenness in the distribution of the applied sewage over the entire bed is of vital importance. Any inequality in application proportionately overworks that portion of the filter receiving the excess, and the character of the filter effluent depends much upon the maximum rates. Cone nozzles normally produce umbrella-like sprays, and while radially the distribution is excellent, certain zones have always, under our tests, received a greater proportion of sewage than others. To overcome this zone inequality the writer designed a nozzle (Figs. 5 and 7) having two cones so spaced and formed that the upper cone distributed sewage over an outer zone and the lower cone controlled an inner zone. The distribution effected is shown diagrammatically in Fig. 8. The nozzle producing such a distribution is called "perconate" from the fact that the major portion of the influent stream rising from the nozzle orifice passes through the lower cone and is diffused by the upper cone over the outer zone. A tapered central spindle (Fig. 7), supporting the cones, is rigidly held in place by the spider. A nut containing a central orifice is capable of being raised or lowered with respect to the tapered spindle, thus effecting a control of the orifice area and making possible an exact calibration of the influent stream. The lower cone is affixed to the central spindle by a thin knife-edge tapered wedge. Through this lower cone is a circular orifice so proportioned with respect to the normal opening in the adjustable orifice below, that ⅘ of the rising influent stream passes through this cone while ⅕ is diffused by it. The vertical distance between the two cones and the angles of elevation of the sewage sprays when leaving the cones are subject to calculation, the controlling factor being the diameter of the area to be covered.

The inequality in the zone distribution by cone nozzles, as previously mentioned, has led to the development of a nozzle (Figs. 6 and 7) to be operated under an undulating nozzle head—the effective pressure to vary from zero to a maximum and back to zero again. The variation of the nozzle pressure will follow a predetermined parobolic curve so that, in theory, each infinitesimal area within the range of the nozzle shall receive an equal volume of sewage. The sewage spray, under this action, rises from the central orifice, gradually spreading out over a greater diameter until the maximum range is reached, after which it recedes in a similar manner. The time required for each undulation may be as chosen, a minute making a satisfactory period.

Such a method of distribution has many advantages, among which may be mentioned the possibility of almost ideal distribution over a circular area, the use of larger nozzle orifices, the better subjection of ice rings, and the positive and almost instantaneous control of the filtering rate.

The nozzle head designed for this system is shown in detail by Fig. 7. It is simple in construction, consisting of two essential parts—a dome and a central spindle. The dome and spindle are of cast brass. A pipe thread is cut upon the lower portion of the dome piece, which is then screwed into a lathe chuck, after which the orifice is accurately drilled, and the spider boss tapped, with centers coincident. The spindle is cast smooth, then buffed and tapped. An adjustment in nozzle orifice area similar to that described in the case of the perconate nozzle is obtained.

Fig. 8. Diagram Illustrating Typical Distribution of Sewage by Adjustable Double Spray or Perconate Nozzle.

Undulation of the sewage sprays may be controlled by one central valve which will determine and define the cycle of undulation of all the nozzles within its particular system. The extent of a nozzle system controlled by one valve varies with local conditions. Filtering rates are immediately controlled by changing the adjustment of the master-valve, thereby increasing or decreasing the period of minimum nozzle pressure.

Another nozzle, entirely different in principle from those above described, consists of a six-winged cone supported directly over a single orifice through which the sewage rises. The winged cone is suspended by a vertical spindle which freely turns within a central hub supported by two upright side posts. A cotter pin serves to prevent the winged cone from dropping out when not in use. The upper end of the vertical spindle is pointed and immediately above it is a glass plate, projecting through a horizontal slot in the central hub, which provides a nearly frictionless thrust bearing. When in use the rising sewage is diffused by the central cone uniformly upon the six blades, which are shaped in a manner similar to those of air blowers. The force with which the sewage strikes the blades causes the winged cone to revolve rapidly and, owing to the curved form of the blades, the individual drops of sewage leaving the distributor have widely varying angles of elevation. The angle of elevation of a drop the instant it leaves a wing is a function of the horizontal distance which it will travel, and from this fact it is possible so to form the blades that the area within the range of the nozzle will be completely covered. Under the conditions existing in the local tests this style of nozzle has completely wetted the filter area and has distributed the sewage with high efficiency, although not with absolute uniformity.

The nozzle studies have shown that the problems presented in the application of sewage to

large areas, as in the case of full sized works, are quite different from those met in filters of the size used in the local tests (0.001-acre). The revolving winged-cone nozzle, while it has effected excellent distribution and has been used through a considerable period upon test filters, would not, it is believed, be applicable to municipal plants in their regular operation.

In the application, upon large beds, of fixed sprinkler heads, each capable of distributing sewage over a definite circular area, it is evident that the area wetted is but 78% of the area of the circumscribed square. Hence 22% of the total filter area does not receive sewage, and is therefore idle. A filter under this condition is treating but 78% of what it ought to do if the distribution of the applied sewage were perfect. The maximum coefficient of distribution which may be obtained by regularly spaced fixed sprinkler heads, each covering a circular area, is .78, and therefore any means of increasing this coefficient, that is, any means tending to distribute sewage over the unwetted corner areas, is of much value.

Many attempts have been made, by the writer, to increase this coefficient with the result that, by means of a specially-formed cone, fully 90% of a square area has been brought within the control of a central nozzle. The nozzle used has been similar to the "umbrella spray nozzle" shown in Fig. 7, except that each quadrant of the inverted spreader cone has a vertical cut. A film of sewage leaving the spreader cone tends to travel in the direction of the tangent to the surface curve of the cone at the point of departure, and the horizontal distance traveled by a drop before striking the filter surface is dependent, in part, upon the angle elevation of its line of travel at the instant it leaves the cone. By the vertical cut in the spreader cone, as above described, it is possible to obtain a great range in the angles of elevation of the sewage film and consequently a considerable range in the horizontal throw. One nozzle working under an effective head of 7 ft. had a horizontal range of 7 ft. along the line of minimum elevation of the sewage film and a range of more than 8½ ft. along the line of maximum elevation. Between these lines the throw varied in a natural way from the maximum to the minimum.

FILTER GALLERY.—Between the sand and the sprinkling filters is a depressed gallery (Fig. 2) having a floor 2 ft. below the bottom of the sprinkling filters. This gallery is so arranged in relation to the piping system and filters that all sampling of plain sedimentation and septic tanks, sand, contact and sprinkling filter influents and effluents is done within the gallery; in fact, all of the regular working samples are collected here, excepting those from the grit chamber and the crude sewage, which are taken inside the laboratory building. Beneath the gallery is a main drain which collects the filter effluents and sampling wastes, and to this drain is connected a catch-basin receiving the surface waters draining from the gallery floors.

LABORATORY.—In Fig. 1 is shown the general plan of a substantial wooden frame building, 16 × 24 ft. in plan, which was constructed for the testing work. The building is divided into two rooms. One room contains, among other equipment, the pumping machinery, the mixing and agitating devices for chemical precipitation, and also the steam bath and drying ovens, an incubator for the study of putrescibility of effluents, another for bacteriological cultures, a refrigerator for sample storage, and water stills and condensers. The other room contains apparatus requisite for a well-equipped chemical and bacteriological laboratory for water and sewage analyses.

The study of the local sewage and its purification, which has been continued during the past fifteen months, is now substantially finished and plans for the development of the future works are being made. The sewage as received for treatment will be exceptionally fresh and its purification is to be effected by the application of a septicized tank effluent to sprinkling filters at a net rate of two or more million gallons per acre per day. The work is being done under the direction of the Board of Public Works by Mr. R. A. Cairns, M. Am. Soc. C. E., City Engineer, with the writer in immediate charge of the experiment station and the design and construction of the works, and with Mr. Harry B. Hommon as chemist and bacteriologist.

THE RECENT DETERMINATION OF THE FIGURE AND SIZE OF THE EARTH FROM MEASUREMENTS IN THE UNITED STATES.

A paper on the above subject was read by John F. Hayford, Inspector of Geodetic Work and Chief of the Computing Division, Coast and Geodetic Survey, Washington, D. C., before the Mechanical Science and Engineering Section of the American Association for the Advancement of Science, at the New York meeting, Dec. 28, 1906.

The investigation of the figure and size of the earth to which the paper referred is interesting because it involves radical and successful changes from the methods heretofore used in geodesy, because it furnishes a proof of the weakness of the material composing the earth, and because it constitutes an unusually large contribution by any one nation to the problem of determining the information sought.

It is based upon 507 series of astronomic determinations made at many different stations, and upon continuous triangulation extending from the Atlantic to the Pacific, and from the Great Lakes to the Gulf of Mexico.

The investigation shows that, for the United States and adjacent areas, the assumption sometimes tacitly made that the material composing the earth is sufficiently rigid to maintain the continent in position, in the vertical sense, is far from the truth. On the contrary, the assumption that the earth is in the condition called isostasy is a comparatively close approximation to the truth. In other words, the United States is not maintained in its position above sea level by the rigidity of the earth, but is, in the main, buoyed up, floated, because it is composed of material of deficient density.

It was also ascertained that this material of deficient density probably extends to a depth of about 70 miles below the surface.

The flattening of the earth, according to this investigation, is between the values assigned by Clarke and Bessel. Both the equatorial and the polar dimensions are found to be larger than they were stated to be by Bessel or Clarke, or any of the other principal investigators along this line.

THE FAILURE OF A 175-FT. REINFORCED-CONCRETE CHIMNEY AT LOUISVILLE, KY.

The failure of the reinforced-concrete chimney of the Seelbach Hotel at Louisville, Ky., during a heavy wind on Jan. 19, was described by Mr. D. R. Lyman in our issue of Feb. 7. We have since received from the contractors some further particulars in regard to the design and construction of this chimney, and this information we print below as supplementary to the former article.

After carefully reading and considering the article which appeared in your issue of Feb. 7, in reference to the partial collapse of the chimney at the Seelbach Hotel, Louisville, Ky., we feel that a statement from us at this time would be proper. While we are convinced that Mr. D. R. Lyman desired to be fair in every way, and has given the best possible account from the information he had at hand, there are other facts which we feel should be placed before your readers. There being such a large amount of reinforced concrete work under construction and in contemplation, anything tending to discourage its use would be an injustice to the engineers and contractors engaged in this work, as well as unfair to the purchasers. We will therefore endeavor, without going into detail, to give you the conditions which governed in this case, together with the reasons we find for the accident.

This chimney was erected upon a foundation furnished by the purchaser and built in 1904. The matter of using this foundation was gone into quite thoroughly by us and was not at first considered feasible, but upon being given reasonable assurance by the purchaser, we consented to use it. We mention this, for although it did not cause the accident, we believe it indirectly had something to do with it. We would also direct attention to the proportions of the chimney. The height was 175 ft. above the grade line, and the inside diameter 4 ft. 6 ins., making the outside diameter below the offset 6 ft. 10 ins. and above the offset 5 ft. 4 ins. This is an unusual height as compared to the diameter, and one which requires great care in the design and also in proportioning the materials.

The vertical reinforcing consisted of steel tees 1¼ × 1¼ × 3/16 ins., and the horizontal of similar tees 1 × 1 × ⅛ ins., placed 3 ft. apart (instead of 2 ft., as stated in your article). In the latter respect our specifications have been changed on all the chimneys which we have built subsequently to this one; instead of the tee bars we use for the horizontal reinforcement a ⅝-in. round bar overlapping 24 ins. and placed 18 ins. apart instead of 3 ft., as in the Seelbach chimney. However, although the reinforcement is a matter of great importance, it did not show any breaking or signs of having reached its ultimate tensile strength in this chimney. The cement was of high grade and tested out excellently. The sand, however, was rather fine and was not analyzed, a practice which is closely followed at the present time and has been for several years past. This sand, we believe, contained a small percentage of lime particles, and this in connection with the fineness prevented the concrete reaching the ultimate strength and hardness which it should have possessed, and also prevented it from adhering throughout to the reinforcement. As stated, we carefully analyze all sand and do not use anything but a very sharp torpedo sand, which does not contain any lime particles, and hence will not disintegrate or deteriorate under high temperatures. In your article you state the mixture used was eight or nine to one. This is not correct, as we have never used to exceed a 1:4 mixture.

While putting in the foundations for the new building which is adjacent to the chimney foundation, the latter foundation was disturbed, causing it to settle. This, combined with the fact that the concrete was poor, owing to the fine sand used, caused the cracking and ultimately the partial collapse. After the settling of the foundations and the cracking appeared; steps were taken to secure the chimney to the steel work in the new building, and there had been elected a large scaffolding on the outside of the chimney. The increased surface this scaffolding (which had been erected to the top of the chimney) gave to the wind increased the strains in the chimney, and considering its weakened condition had much to do with the accident.

In conclusion we would state that we have constructed about 300 chimneys, and have had only two cases of accident after completion. Of this record we are justly proud. In the two cases where trouble has occurred, we have met it without word or argument, and have replaced the chimney and paid for any and all damages done, although for the latter we are not legally liable.

RAILWAY CONSTRUCTION IN CANADA is progressing rapidly and includes a number of very important enterprises. It is stated that over 5,000 miles of line are now under construction between the Great Lakes and the Rocky Mountains, distributed as follows: Grand Trunk Pacific Ry., 1,900 miles; Canadian Northern Ry., 1,500; Canadian Pacific Ry., 1,400, and Great Northern Ry., 1,000 miles. For some years the Canadian Pacific Ry. has been improving grades and curves on its prairie section, in order to better meet the competition with other and newer lines, while on the line between Winnipeg and Fort William the double tracking has been completed for about 100 miles. The Canadian Northern Ry. has applied to the government for permission to build its Pacific coast extension (from Edmonton) through the Yellowhead Pass, where the Grand Trunk Pacific Ry. will also cross the Rocky Mountains. The latter road, which is backed by the government, has the grading nearly completed from Winnipeg to Edmonton. The Hudson Bay route is again attracting attention, and the Canadian Northern Ry. has started a line from Prince Albert in that direction, while the government of Manitoba is reported as intending to finance a project for a direct line from Winnipeg to Fort Churchill, a distance of 600 to 700 miles. Although navigation is only open for about six months it is thought that a grain route to Europe might be operated from Hudson's Bay.

ABOUT 70,000 TONS OF RUBBER were produced in 1906. Some 60% of this total came from South America, Brazil alone providing at least 35,000 tons, or one-half the world's production. The Brazilian output comes almost exclusively from the Amazon region. Only about 1,000 tons of it is plantation or cultivated rubber; but planting is greatly increasing, particularly in the East Indies. A London note says that Ceylon has 100,000 acres planted; Sumatra and nearby islands, 90,000; Borneo, 12,000; Java, 20,000 acres; India, some 10,000 to 20,000 acres, etc. The prices of natural and plantation rubber of equal grade are approaching each other; the former difference of 20 to 25 cts. per lb. in favor of plantation rubber has now decreased to 10 cts.

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By a remarkable coincidence, our comments of last week on the danger of very fast trains received almost immediate emphasis by another high-speed train accident. This most recent wreck, moreover, occurred on the very line whose proposed 16-hour train between New York and Chicago furnished the text for our comments; and the fastest train that now makes the run in question figured in the accident. The 18-hour train of the Pennsylvania Railroad, westbound, left the track last Friday night on a curve near Johnstown, Pa., where the line runs along the steep bank of the well-remembered Conemaugh River. By great good fortune no one was killed, although three of the four cars rolled down the steep bank and turned over in shallow water at the river's edge. Up to the present, two explanations for the derailment have been advanced: failure of a brake-hanger on the engine, and failure of the track. The first of these has no particular relation to high speed, but the second, obviously, is vitally concerned with speed, since the destructive action of rolling stock on track increases rapidly as the speed is increased.

It is accidents of this kind which are responsible for the increasing public distrust in high-speed railroading. We may speak of this phase of the matter with greater freedom for the reason that the Johnstown derailment is free from that element of human error, that terribly frequent "one man's mistake," which gives an added touch of bitterness to the contemplation of most of our great railway wrecks. Let us assume, as we fairly may, that the track at the point of derailment was of good construction and well maintained, that the rolling stock had been inspected and found in first-class shape, and that some unforeseeable failure of track or car equipment caused the wreck: "Surely," the railway officer may say, "this accident cannot be made a matter of blame to us! And surely there is nothing in the circumstances to put the fault on the speed of the train!" Conceded, if only for the sake of argument. The point then is, that for the very reason that the accident was of the unpreventable kind, the layman inevitably conceives distrust and fear of high speed; for, if such accidents will happen in spite of every care, how can he afford to take chances of the worst consequences by riding at the highest speed? The probability of serious result is in ratio to the square of the speed, we may say. At a 60-mile speed it is half again as great as at 50 miles per hour, at 70 miles twice as great. But as concerns the moral effect on the public these ratios of 1½ and 2 become at least 3 and 4. And let it not be forgotten that a popular apprehension directed against very high speeds cannot fail to cast some shadow even on moderate-speed traveling.

These two recent derailments on the New York Central and the Pennsylvania, both occurring on curves, on well-maintained track, direct renewed attention to the thick veil of mystery—and ignorance—which surrounds the subject of the behavior of railway vehicles on curved track.

In the New York Central wreck investigation, the Coroner's attorneys have assumed, doubtless, in all honesty, that the railway engineers could compute the stresses in rails, spikes, wheel flanges, etc., with some such accuracy as they would the stresses in a bridge member. The railway officers and engineers have consequently been subjected to most savage criticism in the public press.

The fact is, however, that there is no science of "curve mechanics" as there is of bridge mechanics; and for the most part the proportioning of track and trucks for curve stresses must be done by practical experience alone. It is yet to be demonstrated whether the New York Central engineers were in any way remiss in constructing the curve where the accident occurred.

The detailed description in this issue of working methods in the Pennsylvania R. R. Hudson River tunnels (for which we acknowledge our indebtedness to Mr. James Forgie) adds very considerably to the literature of soft-ground tunneling, and indeed, more broadly, to the literature of tunneling in general. We have already expressed the opinion, in commenting on the first half of the paper (in our issue of Dec. 13, 1906), that it is the most important monograph on shield tunneling ever published. The present or second half of the paper well supports this estimate, which is the more true because the Hudson River work, both at Morton St. and at 32d St., involved the unprecedented condition of long-continued progress through a semi-fluid soil.

The art of shield tunneling, be it observed, has in the past been in continuous evolution, presumably not yet completed. Sufficient proof of the fact is found in a survey of the shields used in the various tunnels listed in the table near the end of Mr. Forgie's paper. Some of these shields comprised nothing more than the bare essentials of a cutting-edge, without bulkhead or doors, fitted with hand screw-jacks for shoving; others of the list were structures of great complexity and cost. Even to-day there is no convergence toward a unified type. Yet ultimately the functions of all shields are identical. The paper in question clearly exhibits the fact, we believe, that a tunnel-shield is inherently nothing more than a means of supporting the face timbering and the roof poling; ultimately, the success of the work depends almost wholly on the skill of the working force, from Chief Engineer to laborer, in holding up the face. From this fact the statement follows almost directly that a shield is efficient in ratio as it facilitates thorough timbering of the face and safe and rapid removal of material. Beyond this condition, shield design is affected only by the possibility of mischances or failures at the face, or rather by the projector's ideas as to how such mischances, always possible, may best be minimized and overcome.

The fact that the advance of the Hudson River shields through the unstable, highly plastic Hudson silt was accomplished by a displacement method, without any face-timbering whatever, may seem to be somewhat at odds with the preceding thoughts. But two things must be borne in mind: First, that the most anxious portion of the Pennsylvania Hudson River tunnel work was not in the silt, but in soft ground landward of both banks, in piling, riprap and similar obstructions. Second, that even in the silt it becomes necessary on occasion to undertake a timbered advance. Thus, the first entry of the shields into the silt, until the hood could be removed and a full cutting-edge substituted, was made with timbered face. Similarly, in running out of the silt into a different soil it is necessary to go through the doors of the shield and gain a protected face in silt before further progress is possible. This was the case in the Morton St. tunnels, two years ago, where the entire advance, on resumption of work after a decade of idleness, was made from the west headings.

In the Morton St. tunnels, by the way, a much more striking example of timbered work in the Hudson silt was afforded. When the completion of these tunnels was taken hold of by the Hudson Companies, one of the shields was within 50 ft. of a rock reef. A timbered heading was carried out from the shield, in silt, to the rock base. Mr. Charles W. Jacobs, Chief Engineer, describes this as follows:

> Practically a workshop was built ahead of the shield and in the silt before reaching the reef, and a steel apron built across the front of the shield, so as to provide necessary cover for the men drilling rock ready for blasting before it could proceed on its journey to New York.

This remarkable feat was accomplished under 38 lbs. air pressure.

MUNICIPAL SEWAGE EXPERIMENT STATIONS.

A dozen years ago much surprise would have been created by the prediction that ten years thence American cities would just be starting a remarkable series of experiments on the treatment of sewage; that the Massachusetts experiments at Lawrence, then already classical, would still be in progress, with the prospect of many more years of profitable work; and that in 1903 there would be initiated by the Massachusetts Institute of Technology an exhaustive experimental study of the treatment of sewage, in many respects paralleling the Lawrence experiments, although not duplicating them. The question naturally arises whether, after all the experimental work here and abroad, after some 30 years of sewage treatment by American cities and 50 years of much more varied experience in Great Britain, sewage disposal can be said to have passed the experimental stage? The question admits of either a positive or negative answer, according to one's point of view. Sewage treatment is no longer in an experimental stage when one considers the many plants in successful operation and the large number of thoroughly competent and experienced engineers, chemists and bacteriologists in America and Europe who are ready at a moment's notice to attack with confidence any sewage problem that may be placed before them. But at the same time the art may be considered experimental when looked at in detail and with regard to the many phases of the subject on which not only more light, but much more light, is needed.

In contrast with sewage treatment, the art of water purification appears to be in a much more advanced and settled state. For many years past, British and continental engineers have to a large extent regarded the design of water purification plants as a matter of following well-established precedents, merely varying details to suit local conditions. In the United States, with our great variety of geologic and climatic conditions affecting the character of natural waters, the attendant problems have been more various and complicated and have called for no little experimentation. While it is to be expected that many changes and advances in water purification will be made in the future, yet on the whole the art may be said to be in a settled state, especially as compared with the art of sewage treatment.

Many of the open questions relating to the main problems of sewage disposal, as compared with those of water purification, are largely due to the complexity of the sewage problem, which complexity is due in turn to the complex character of sewage itself, its unstable condition and its many and great variations in character. These differences in character vary not only as between city and city, but also from day to day and even from hour to hour within any one municipality. Water subjected to purification is much less variable in point of time, and, as a

rule, considerably less variable as a matter of locality.

Although water purification may almost be said to be stereotyped in some foreign countries, and in America is certainly so well established in principle that the changes now occurring are chiefly along well recognized lines, the art, at least in America, did not assume this state until after the experiments with slow sand filtration conducted at Lawrence for the Massachusetts State Board of Health, and the large scale municipal experiments with mechanical filtration at Louisville, Ky., and with both mechanical and slow sand filtration at a number of other cities. If the comparatively simple and specific problems of water purification demanded so much experimental work, how much more need is there, then, of investigation to determine the best means of treating so complex and so locally variable a substance as sewage?

The sewage problem in the United States seemed comparatively simple in the early '90's, after the publication of the two-volume special report of the Massachusetts State Board of Health and after the establishment of a large number of intermittent sand filters for the treatment of sewage in Massachusetts and a few other American states. It then seemed that intermittent filtration, with sewage farming as a possible alternative, would become the rule in America. It soon became apparent that, owing to the lack of suitable land, favorably situated in relation to cities, intermittent filtration was impracticable in many parts of the United States, exactly as both it and sewage farming had proved to be impracticable for many British municipalities. The greater scarcity of land suitable for sewage treatment in Great Britain, combined with the greater pressure for some purification there owing to the smallness of the streams available for the reception of sewage, forced that country to proceed more rapidly in sewage works development than was required by the corresponding conditions prevailing in the United States. Accordingly, British sanitarians seized with avidity a number of suggestions for the rapid treatment of sewage made available by the publication of the results at the Lawrence Experiment Station of the Massachusetts State Board of Health, and out of the many claims for new and various methods of treating sewage advanced in Great Britain there soon emerged with clearness the septic tank as an alleged improvement upon either simple sedimentation or chemical precipitation, as a preliminary process, and the contact bed on the one hand, and the percolating or sprinkling filter on the other, as a substitute for intermittent sand filtration and broad irrigation or sewage farming. These newer and more rapid systems of treatment have been given the tests of both experiment at temporary plants and experience at permanent plants in Great Britain and to a slight extent on the continent, and they have also been tried in a much more limited way in America.

It might seem that after 20 years of sewage experiments by the Massachusetts State Board of Health, and after various experiments abroad, at the Massachusetts Institute of Technology, and the recent extended studies at Columbus, O., no further experimental work in the treatment of sewage was necessary. But the many variations in local conditions and the complexities of the problem already mentioned will demand further local tests to determine the best methods of meeting those conditions, besides which there still remain many unsolved problems. It would be unreasonable to expect that general sewage experiment stations like those at Lawrence and Boston (Massachusetts State Board of Health and Massachusetts Institute of Technology, respectively) could afford answers to all the questions that arise in connection with this complex subject. From their very nature, these stations must address themselves largely to the more general phases of sewage treatment; since their primary object is to discover principles of value to what may be called their constituency. In the case of the Massachusetts State Board of Health, the constituency is of course the state named, the area of which is relatively small, while its soil, climate and industries are very unlike most other parts of the United States, and still more unlike England, to which country we must still look for leadership in many phases of sewage treatment. Other limitations on the applicability of the data of the Board and the Institute are the necessarily small size of many of their experimental units, this being particularly true of most of the Lawrence tests, except those conducted in the large outdoor tanks devoted to intermittent sand filtration. These small units mattered less, perhaps, when most of the experiments were confined to intermittent filtration, but with the advent of the septic tank and rapid filters, and particularly of the percolating or sprinkling filters, the need for larger units increased. With the percolating filters, one of the chief problems is how to secure and maintain a uniform distribution of the sewage, in point of both area and time. Manifestly, the distributing apparatus of a laboratory filter is a much simpler affair than one for a large municipal filter. At Lawrence, and for some time at the Research Laboratory of the Massachusetts Institute of Technology, also, the distributors for the percolating filters were merely tilting vessels, which are as far from the sprinklers used on the British percolating filters as could be imagined. We are pleased to note that at the Technology station this form of distributing apparatus has been abandoned and that pending the trial of more suitable devices the publication of the detailed results of the percolating filters is being withheld.

It is only fair to the Lawrence station to note that its experimental work has been supplemented by long-continued observations of the practical working of sewage purification plants throughout the state; and it should also be noted that the workers at the Technology station have made visits to plants in various parts of the country and have made studies of special sewage disposal problems.

Aside from the able and instructive investigations in connection with a very small proportion of existing American sewage purification works, notably at Worcester, Brockton and Clinton, Mass., and at Pawtucket and Providence, R. I., the first American city to establish and operate a sewage experiment station was Columbus, O. (See Eng. News, Oct. 20, 1904, for illustrated description, and March 29 and April 5, 1906, for abstracts of the report on these experiments.) The Columbus testing station and the valuable report on its operations marked an epoch in American sewage purification. They called emphatic attention to the desirability of spending a small sum in experimental work (say the equivalent of the interest for one year on the probable cost of the projected plant), in order to throw light on both the design and the operation of the permanent works, thus lessening the risk of expensive and troublesome mistakes and perhaps saving many times the cost of the experiment.

In view of the valuable teachings of the Columbus experiments and the reasons for continuing such work which we have outlined above, it was to be expected that other municipal sewage testing stations would follow. Elsewhere in this issue we describe in detail two such plants: the one at Waterbury, Conn., ranking second in chronological order, and that at Baltimore, Md., standing third among American municipal sewage experiment stations, established in advance of and to assist in the design of works for treating the sewage of the whole city. While both these testing stations will aid in solving the whole problem of the design and operation of the permanent works that are to follow, each was established more particularly to throw light on one or two special local questions. At Waterbury the topography and other considerations made it impracticable to place reliance on intermittent sand filtration alone, on which almost sole dependence has heretofore been placed in New England. In turning to percolating filters, the city was confronted with the fact that such filters had never stood the test of the severe winter climate of New England. It therefore seemed almost necessary to try them on a small scale before attempting to design and operate a plant including that type of filters. At Baltimore the Columbus experiments might perhaps have been accepted as applicable, but here a desire to protect the oyster industry of Chesapeake Bay had put heavy restrictions on the character of the sewage disposal works, and it was important to determine whether it would be safe to stop short with septic tanks, percolating filters and sedimentation basins instead of adding high-grade intermittent sand filters. An important secondary line of investigation at each place was the details of sprinkling apparatus—stationary spray nozzles being proposed at Worcester, and electric motor-driven rotary sprinklers at Baltimore. Our articles will show that at each city unique sprinkler designs are under consideration.

The attention given to the distribution of sewage on percolating or sprinkling filters in the United States bids fair to put this country in the lead as regards that very important point in sewage filter design. The Columbus engineers were the first, so far as we know, to take up the subject in a thoroughly scientific manner. The Sanitary Research Laboratory of the Massachusetts Institute of Technology is giving the matter careful study. The articles elsewhere in this issue give evidence of further efforts to perfect distributing apparatus. We are quite aware that no little ingenuity has been devoted to the design of sewage sprinklers in England. The number of such devices in use there, many of which are proprietary, is really bewildering. But so far as we know, scarcely any tests of these devices have been made to determine with accuracy how perfect a sewage distribution they effect. Even had such tests been made, it might be necessary to repeat some of them in this country in order to learn what variations would result here during the extremely cold weather of large portions of the United States.

For the benefit of those not familiar with the detail of sewage treatment, it may be mentioned in passing that the use of sewage sprinklers is confined to percolating filters, through the relatively coarse material of which the sewage percolates or trickles in small streams, making a uniform distribution of sewage over the whole area of the bed essential if the full area is to be utilized. This uniform distribution is all the more essential in view of the rapid rate of treatment, or in other words the short time required for the sewage to pass through the beds. In contact beds, the underdrains are controlled by gates, and the interstices of the filtering material are therefore completely filled and the sewage held therein as long as desired. This ensures thorough distribution, unless the portions of the bed or the carriers are allowed to become clogged, or the carriers are improperly designed. Even with improper design of the carriers, the sewage will ultimately find its way through the whole bed, but the delay would be undesirable. In intermittent sand filters, the effluent outlets are free, but the usual fineness of the filtering material tends to spread the sewage over the whole area. Any deficiency in distribution is supposed to be guarded against by the design of the distributing system.

The actual distribution on different sizes of sand, in intermittent sand filters, and with different arrangements and spacings of the distributing channels, might perhaps be a profitable subject for study in connection with either permanent or experimental sewage works. It is conceivable, also, that peculiar local conditions might make it well worth while to investigate the value of sprinklers for intermittent sand filters, although such sprinklers would involve large expense unless by means of preliminary treatment or otherwise a high rate of filtration were possible.

The suggestion just made is but one of many that might be offered as possible subjects for future experimental work. Much work of this class might be done, and some would be best done, at regular municipal sewage works, rather than at experimental stations.

The mention of regular sewage works suggests the desirability of both observations and experiments to secure more definite and reliable cost data. With the exception of a very few works

indeed, little attention is paid to this most important subject. At the experiment stations, obviously, specific cost data cannot readily be obtained, since the conditions prevailing are so different from those found in practice. Valuable data for use in making cost estimates are of course provided by experiment stations; as, for instance, the amount of material scraped from intermittent filters for each 1,000,000 gals. of sewage passing them. But at municipal sewage works, valuable cost data could be secured year after year if only a little intelligent attention and small expense were devoted to the subject. The expense, it hardly need be said, might readily be saved many times over by the valuable suggestions secured. It would seem hardly necessary to add that cost data should include capital charges as well as operating expenses when it is desired to make comparisons between the economy of various methods of treatment. But so far as we are aware, no American city has yet taken capital charges into account in making up the few meager records of cost which are thus far available in this country. Conditions in this respect are somewhat better in England, but so far as we know capital charges there are not ordinarily taken into account except in connection with sewage farms.

In conclusion, we will touch very briefly upon a line of sewage research that has but recently come to the front, but is creating a great deal of interest and speculation in both Great Britain and the United States. This pertains to colloidal matter in sewage and their relation to the clogging of filter beds. Colloidal matter, in so far as we can define it in very brief space, is solid matter in solution which is subject to deposition in a gelatinous state after sewage appears to have been well clarified. We cannot dwell further upon the subject at this time, except to suggest the possibility that it might well be taken up at the Lawrence experiment station and at the Sanitary Research Laboratory of the Massachusetts Institute of Technology. Doubtless useful work on this subject might also be done at well-equipped municipal experiment stations, as we understand has already been begun at the permanent laboratory of the sewage works of Manchester, England. A large part of the information now readily available on the subject, or references thereto, may be found in the very interesting paper and discussion on "The Elimination of Suspended and Colloidal Matters from Sewage," by Lieut.-Col. Alfred S. Jones, M. Inst. C. E., and Dr. William Owen Travis, as found in the Proceedings of the Institution of Civil Engineers, Vol. CLXIV., 1905-06, Part II. Briefer references to the same subject are made in the discussion on "The Relation of Suspended Matter in Sewage to the Problem of Sewage Disposal," by Harrison P. Eddy, Assoc. M. Am. Soc. C. E., and Almon L. Fales, in the Journal of the Association of Engineering Societies for September, 1906. Each of these papers, with its attendant discussion, abounds with information on many phases of sewage treatment, and each contains numerous suggestions for future observations and experiments.

LETTERS TO THE EDITOR.

The Formula for Conditions of Economy in Reinforced Concrete Beams.

Sir: I desire to call attention to the fact that eq. (1) of Mr. Hanna's article on "Economic Design of Reinforced Concrete," appearing in your issue of last week (see pp. 203 and 204) is practically identical with eq. (10c) of the writer's discussion of the paper by Capt. Sewell, published in Transactions American Society of Civil Engineers for June, 1906 (see p. 358 of that issue). The notation is of course different, and Mr. Hanna's expression for cost in his eq. (1) refers to a width of "b" inches (constant), whereas the writer's "x" has to do with unit width. Also Mr. Hanna considers the stress in outer fiber of the concrete to be the safe working stress "c," a constant, while the stress in the steel is variable, being dependent on the ratio "y," which is the only variable in the right-hand member of eq. (1). In the writer's eq. (10c), the stress in the steel, T, is constant; the stress in the outer fiber of the concrete depends on the ratio "r" (Mr. Hanna's "y"), and this "r" is the only variable in the right-hand member of (10c). The writer's "m" is the bending moment for a beam of unit width while his "c" and "p" are Mr. Hanna's "r" and "R," respectively. With these relations considered it is easily shown that Mr. Hanna's eq. (1) is the same thing as the writer's eq. (10c).

Sincerely yours, I. P. Church.

Cornell University, Ithaca, N. Y., Feb. 23, 1907.

Kutter Formula Coefficients Used in Designing Canals and Tunnels on the Truckee-Carson Irrigation Project

Sir: In Engineering News of Oct. 18, 1906, is an interesting article on the Truckee-Carson Irrigation Project. It appears that for calculating the section of canal, whether in cutting or tunnel, Kutter's formula is used, with certain coefficients varying with the nature of the section. Could you, or the writer of the article, kindly inform me if, on testing the flow through the tunnels, the high coefficient of discharge used (.012) proved to have been warranted, and if so, how the test was made (p. 395). The same point arises in the concrete-lined section of open channel where 0.15 was used (p. 394).

In India a much smaller depth of canal would have been used and a coefficient of 0.20 adopted in ordinary earth cutting; and in calculating for a tunnel to discharge 12,000 cu. ft. per sec. orders were recently given by the Government Inspector-General of Irrigation to use a coefficient of .017.

I should be glad to know if the unusual proportion of depth to bed width of the Truckee Canal permits of a higher coefficient being safely assumed.

Yours truly,

C. T. Mullings.

Avinigudda, Kistna District, Madras Presidency, India, Jan. 14, 1907.

A Method of Scaling Earthwork Quantities from a Profile.

Sir: The accompanying equations may be as old as the hills, but the idea of the estimating slip may be a novelty.

Assume:

W = width of roadbed.

r = side slopes, expressed as horizontal to vertical.

h = cut or fill + $\frac{W}{2r}$.

β = tan of transverse slope of ground.

A = end area.

Y = cu. yds. in 100 ft. station.

Then

$$A = \frac{r h^2}{1 - r^2 \beta^2} - \frac{W^2}{4 r},$$

and

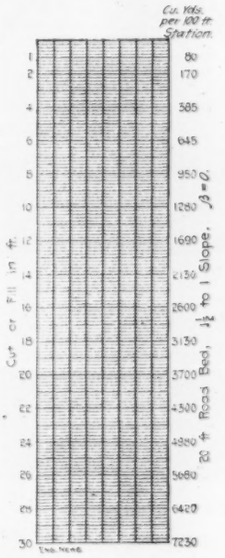
$$Y = \frac{100}{27}\left(\frac{r h^2}{1 - r^2 \beta^2} - \frac{W^2}{4 r}\right).$$

Now in a given case assume:

$W = 20$ ft., $r = 1\frac{1}{2}$ to 1, $\beta = 0$, then

$$Y = \frac{50}{9} h^2 - 246\frac{74}{81}$$

$$h = \text{cut} + \frac{20}{3}.$$



With these equations a series of values of Y can be derived from assumed values of cut (or fill) and placed on a slip of profile paper, as is shown in the accompanying drawing, the scale of c being the same as on the profile from which the volumes are to be taken. This slip can then be applied to the profile and the cu. yds. per station read directly without noticing the exact numerical value of the cut or fill. It can be used of course only on rough estimating work.

Very truly, W. E. Davis.

Edmonton, Alta, Feb. 1, 1907.

Inches or Feet and Inches in Dimensioning Drawings?

Sir: Will you kindly tell me whether there is any uniformity of custom as to when dimensions should be given in inches and when in feet and inches. Some drafting rooms require that all dimensions under two feet shall be stated in inches, as 17", and over two feet in feet and inches, as 2'-3". Is this rule generally accepted?

Sincerely yours,

Otho M. Graves.

3733 Locust St., Philadelphia, Pa., Feb. 18, 1907.

[As a general rule it may be said that all dimensions under a given amount, 2 ft. as a rule, should be recorded in inches, and all dimensions above that amount in feet and inches. This rule is subject to change in the various classes of drafting. For example, the average carpenter does all his measuring with a two-foot rule scaled to inches. He carries in his mind distances up to 2 ft. in inches, so all drawings made for his use are preferably so dimensioned. On the other hand, the machinist is very apt to do all his measuring in inches, since very little of his work will run over 10 ft. or 120 ins. in length and is very easily understood and carried in the memory by inches. To him, therefore, a drawing dimensioned entirely in inches would be most intelligible. As an example of this use of inches note the 110-in. wheel-base of the latest automobiles.

The object of a drawing is to enable the workman to carry out the ideas of the designer and he should be able to do so without reducing feet to inches or the reverse, with chances for error, in the process.—Ed.]

A Native Irrigation Plant in the Philippines.

Sir: I enclose a picture showing native irrigation in the Philippines. The site is in Pangasinan Province on the road between Dagupan and Baguio, and the wheel can easily be seen by travelers on the Benguet road.

With the exception of the axle and two main timbers at each end of it, the whole system is constructed of

A Bamboo Water Elevator in a Philippine Irrigation System.

bamboo and bejuca. The bamboo pipe carries the water for a distance of about a mile, and it is then diverted in numerous small ditches. The wheel is driven, of course, by the current of water through the gap in the earth dam, and the "buckets" fill as they dip below the surface and empty at the top by the difference of angle due to revolution. The Ilocano boy at the left is about 4½ ft. tall, which gives one an idea of the height of the wheel.

Very respectfully,

A. C. Wheeler,
Junior Engineer.

Grande Island, Subig Bay, P. I., Jan. 4, 1907.

Tie Rods in Street Railway Track.

Sir: In Engineering News for Feb. 7 you give an abstract of a paper by Mr. E. P. Roundey, treating for the most part of tie rods in street railway track. This is a matter that some years ago caused the writer some anxiety in connection with brick pavement on a street which had 6,000 ft. of double tracks and where the railway company insisted that the ties were necessary every 6½ ft., notwithstanding the fact that the 9-in. girder rail was spiked to the ties which were imbedded in concrete, the concrete also coming up on the rail for 4 ins.; while the brick pavement was carefully fitted against the rails, specially molded bricks being used to ensure a perfect fit.

The bricks of this pavement were laid with grouted

joints except for the part near the tracks which between the rails and for 18 ins. outside of the rails was laid with sand filled joints to enable repairs to the tracks to be made more easily.

The writer ascertained that in some other cities where brick pavements had been laid the tie rods had been entirely dispensed with and yet the rails were preserved with perfect gage.

In the 6,000 ft. in question the matter was compromised by leaving out half of the tie rods, thus making the work of brick laying a little less difficult. From the point of view of the paver or of the engineer who wishes to secure a good piece of pavement, the rods are a detriment in every way, as they must come between the joints of a block pavement; this necessitates wide joints on a brick pavement and on a granite block pavement the stones have to be badly cut and the joints of several courses have to be spread, very frequently, to accommodate the tie rod.

Perhaps some of your readers can give information of the practice in other cities and can tell whether in their experience it is possible for a gage of the track to change with a carefully fitted brick or block pavement holding the tracks in place.

If a street pavement can hold the tracks with sufficient force to allow of the use of continuous rails with welded joints, it would seem that the pavement could also be relied upon to hold the rails to gage, especially when the lower part of the rail is embedded in concrete.

Mr. Roundey states that the concrete does not seem to be of any use in holding the rails to gage, although the rails are embedded for 4 ins. in the concrete. If the concrete is of good quality it is difficult to conceive why it is not of a great deal of use in keeping the rails to gage. Perhaps in Syracuse, as in some other cities, the street railway companies are so anxious to keep their traffic unimpeded that they allow the cars to pass over the tracks almost as soon as the concrete is laid, thus injuring it materially.

Certainly if tie rods can be done away with in block paved streets the pavement between the tracks will be improved by their absence.

Very truly yours,

Horace Andrews.

Albany, N. Y., Feb. 15, 1907.

Notes and Queries.

T. O. H., Yonkers, N. Y., writes that he received a quotation from a cement dealer of $2.17 per barrel for cement in bags, and when the bill was rendered he was charged 40 cts. per barrel additional for the bags, with a rebate of 30 cts. for bags returned. He wishes to know whether it is not customary for quotations on cement to *include* the package, so that the purchaser and not the seller is entitled to the rebate for packages returned?

We believe the custom of the cement trade is as our correspondent states; but quotations are generally accompanied with a statement of the rebates allowed on returned bags. In case of dispute whether the seller intended the quotation to include packages or not, the current selling price of cement at the time the sale was made should settle the matter as to what was intended.

THE PANAMA CANAL BIDS REJECTED; FURTHER CHANGES IN THE ORGANIZATION.

On Feb. 26 the Panama Canal Commission finally rejected the bids for completing the canal. This action was taken in accordance with a letter from President Roosevelt to the Chairman of the Commission, in which was announced the resignation of Chief Engineer John F. Stevens and the appointment in his place of Major Geo. W. Goethals of the Corps of Engineers, U. S. A. The President's letter in full is as follows:

Sir: I have considered with much care the question whether the commission should accept one of the bids for the construction of the Panama Canal under the proposed contract, or should reject them all. There were two bids worthy of consideration. The bid of the McArthur syndicate at 12½% was the only one which came within the requirements. The Oliver & Bangs bid at 6.75% was rejected as not satisfying the specifications of the invitation.

Mr. McArthur and his associates not objecting, and preferring this course to an invitation for new bids, Mr. Oliver was allowed to perfect his bid with new associates and new financial responsibility; but this permission did not in any way change the situation from what it would have been had Mr. Oliver's bid in its present form been presented on Jan. 13, the day fixed for receiving the bids. Under the invitation for bids the reserved power exists in the commission to reject all bids, and the first question is whether it shall do so.

The purpose of the contract was to secure in the building of the canal the services of the best, most experienced and most skilled contractors in the country at the least risk to them, and at the least expense to the government. An investigation into the two bids above mentioned shows that this purpose of the government has failed.

In each bid the contractors of experience, whose personal services in the work are what the commission has sought, have made arrangements to divide the profits under the percentage bid with bankers or others to whom the contractors have had to look for the needed capital; so that the contractors who are actually to do the work have arranged to accept a comparatively small proportion of the profits accruing under the contract.

In other words, the government by this arrangement is made to pay a high percentage for the use of capital which it might itself have furnished at a much lower rate, while the percentage which the contractors are to receive for the real benefit they are to confer on the government is reduced to very meager and perhaps inadequate compensation. No contract can ultimately operate to the benefit of the government in which the contractor's energy, skill, experience and personal supervision of the work are not adequately paid for.

The defect in the bids which I have described, and which our investigation has made apparent may be due to a defect in the invitation for bids, which perhaps stipulated for too heavy a bond and the investment of too large capital by the contractors, or it may be because the bidders have taken an entirely different view of the money risk involved from that taken by the government.

Mr. Stevens, the chief engineer, who proposed the form of contract which, with modifications was adopted, advises against accepting either bid, because acceptance of either would not, in his judgment, accomplish the purpose he sought. The considerations stated are by themselves sufficient to require a rejection of all bids and a change in the proposed form of contract.

One of the chief reasons for adopting the contract as proposed was that in its main features it was formulated by Mr. Stevens, who was expected to supervise the work as chief engineer. He had had experience with contracts of this character, and he had had eighteen months' actual experience with the work on the isthmus. Less than ten days ago I received a letter from Mr. Stevens, in which he asked to be entirely relieved from work on the canal as soon as he could be replaced by a competent person and that person could become familiar with the work.

I have accepted his resignation. The withdrawal of Mr. Stevens takes away the special reason mentioned for proceeding under the present form of contract.

In order to secure continuity in engineering control and management in the future, I have decided to request you to assign to the office of chief engineer Major Goethals, a member of the corps of army engineers.

It is not my purpose by requesting this appointment to disturb in any way the present organization on the isthmus, which is very satisfactory, nor to interfere with the admirable work now being done by the present assistant chief engineer, Mr. Ripley, and the various heads of departments. The work of construction is going on well and will continue to do so.

The organization already created is increasing the excavation each month, and can be relied upon under competent leadership to make further and constant progress pending a period within which a new form of contract can be devised by Maj. Goethals and his associates, if it is deemed advisable to do the work by contract. The services of the same high class contractors whose bids we are now rejecting, or others of similar standing, may then be invoked in the interest of economy and speed.

Two other competent members of the Engineer Corps, Maj. Gaillard and Maj. Sibert, will accompany Maj. Goethals to the isthmus, and assist him in his labors. They will be appointed on the commission.

Maj. Goethals concurs with Mr. Stevens in advising me that all bids on the present form of contract should be rejected.

I request the commision to take the formal action necessary to reject the McArthur and the Oliver bids, in accordance with the power reserved to it in its invitation.

Very respectfully yours,

Theodore Roosevelt.

The new Panama Canal Commission, therefore, will be made up of the following: Major Geo. W. Goethals, Major D. Du B. Gaillard, Major Wm. L. Sibert, Gen. Peter C. Hains, Admiral Mordecai T. Endicott, Col. W. C. Gorgas, Mr. Benj. M. Harrod and Mr. Jackson Smith.

According to the New York "Tribune's" Washington correspondent, Secretary Taft will sail for the Isthmus about March 20, accompanied by Messrs. John R. Freeman, Alfred Noble and F. P. Stearns. A general inspection of the work will be made and the character of material exposed by test pits on the Gatun dam site and the Gatun lock excavation will be examined.

NOTES FROM ENGINEERING SCHOOLS.

UNIVERSITY OF ILLINOIS.—Ten $500 research fellowships have been established in the Engineering Experiment Station of the University. These fellowships are available to graduates of approved American and foreign universities and technical schools and will be awarded for two consecutive collegiate years, when, if all requirements have been met, the Master's degree will be conferred. Appointments will be made upon the recommendation of the Station Staff of the Experiment Station and upon the approval of the Faculty of the Graduate School and the President of the University, preference being given to those applicants who have had practical experience outside of college.

The Engineering Experiment Station, it should be explained, is a department of the College of Engineering, having been established in 1903 for the purpose of carrying on investigations along various lines of engineering, and the study of engineering problems. The heads of the several departments of the College of Engineering constitute the Station Staff. Investigations are carried on either by members of the staff, a member of the instructional force of the college, a fellow or by special investigators belonging to the Station Corps. Mr. L. P. Breckenridge is Director of the Experiment Station.

A DYNAMITE MAGAZINE BURNED without explosion of its contents in Long Island City on Feb. 22. The official report of Mr. Franz S. Wolf, Inspector of the Department of Combustibles, on the fire is as follows:

At 6.07 o'clock on Friday evening, Feb. 22, an alarm of fire was rung in from the express shed dock, Long Island City. The occasion of said alarm was a fire which broke out in the first-class magazine of S. Pearson & Son, Inc., maintained under license B. I. The fire originated in the interior of the magazine. The magazine keeper had occasion, so reported, to go to the magazine at 5.30 o'clock to remove some dynamite from the bottom and place it on the thawing shelves. At 6 o'clock the fire was discovered. Fireman Callan, detailed to the Bureau of Combustibles, had inspected this magazine at 11.30 in the morning, and had found then 900 lbs. of dynamite therein. The magazine keeper states that there were 16 boxes, or 800 lbs., there at the time of the fire. The dynamite burned furiously but without an explosion.

Fireman Callan, when the fire first broke out, was inspecting the magazine of the United Engineering Contracting Company, on the 35th St. pier, Manhattan. He immediately went over, and was there when the doors were opened. It is impossible yet to tell whether any of the dynamite still remains, as the roof there contained about 1 ft. of sand, which fell upon the dynamite, and the whole was in a frozen condition at the time of inspection on Saturday. I directed that the ruins of the magazine be filled with fresh manure, as well as the surrounding ground, and Mr. Manton, superintendent of Pearson & Co.'s work, made requisition on the Laflin & Rand Powder Co. to send an expert from their factory to clear the debris away.

The fire can only be attributed to one or two causes; First, charring of the wood by the steam pipes; second, the watchman was smoking, or introduced some fire at the time he removed the dynamite to the thaw shelves.

I am inclined to think that it was caused by the steam pipes. The magazine is two years old, and has been used all last winter for thawing dynamite, and up to this date this winter. While steam pipes will not ignite wood, there have been many cases reported, and apparently well substantiated, where the steady action of the heat from the steam pipe has burned the wood near by to charcoal and has caused spontaneous ignition.

This firm has three first-class magazine permits, all authorized to carry 1,000 lbs., and arranged more or less as this one was.

As I consider the keeping of that quantity or any quantity of explosives in the winter time in such magazines without constant, sufficient and efficient supervision (all of which appeared to be lacking), a serious menace to life and property, I respectfully recommend that the permits issued to S. Pearson & Son, Inc., be revoked.

In accordance with the recommendation Commissioner Hugh Bonner revoked the permits of Pearson & Co., and also those issued to the Degnon Contracting Co. for the work on the Belmont tunnel at 42d St. This latter action was due to an accident on Feb. 23. A laborer's pick struck an unexploded dynamite cartridge, in this tunnel, and the explosion which followed killed one man and severely injured two others. Inspector Wolf stated that there had been a great many accidents there from the unexploded shot holes.

THE GROUNDING of the Austrian Lloyd steamer "Imperatrix" near Cape Elaphonici, Crete, Feb. 22, caused the death of 40 members of the crew. All passengers were rescued.

THE BURNING of the steamer "Marion" at Hart's Landing, S. C., Feb. 22, resulted in the death of some 20 negroes. The steamer carried seven white passengers and about 50 negroes. The latter became panic-striken, and about half of them were either drowned or burned to death.

THE SINKING of the American fruit steamer "Hugoma" in the Mississippi River just below New Orleans, La., Feb. 20, by the French cruiser "Kleber," cost the lives of seven stokers. The accident was caused by the swift current of the river carrying the "Hugoma" into the cruiser's path. The latter hit the fruit ship amidships, on the port side, and nearly cut her in two.

THE ROTTERDAM MAIL STEAMER "Berlin", from Harwich, England, to the Hook of Holland, went ashore at the entrance to the latter harbor during a furious gale Feb. 21, and the wreck resulted in the death of 128 persons. The Dutch life savers, after many efforts reached the wreck 30 hours after the accident, and brought off eleven survivors, who were clinging to remnants of the vessel. Three passengers, who were too weak to leave the wreck, were subsequently rescued by the life savers, after having clung to the wreck for 67 hours, this making a total of 14 persons rescued. These with Captain Parkinson, who was washed ashore, are the only survivors of a passenger list and crew of 143 persons. The wreck occurred at the same spot as that of the British steamer "Leeds", which was lost in 1882.

THREE PERSONS WERE KILLED and 16 injured in the wreck of an express train on the Grand Trunk Ry., at Guelph, Ont., Feb. 26. The locomotive remained on the rails, but all cars jumped the track and rolled down a 32-ft. embankment into a swamp.

A FREIGHT TRAIN WENT THROUGH A BRIDGE on the Chicago & Northwestern R. R. near Canning, Dakota, on Feb. 18, causing the death of the engine runner. Floods in the stream are thought to have weakened the structure; one report states that the bridge was 8 ins. out of line when the freight train went on it.

A BUTTING COLLISION occurred on the Inter-Colonial Ry. at Brookfield, N. S., Feb. 26. Two trainmen were killed and two injured, one fatally. The locomotives were wrecked and several cars badly damaged.

DERAILMENT OF A HIGH-SPEED TRAIN on the Pennsylvania R. R., on the night of Feb. 22-23, injured a trainload of passengers but caused no fatalities. The 18-hour train from New York to Chicago, the fastest train on the line, left the track on a 3¼° curve at Mineral Point, near Johnstown, Pa., on the bank of the Conemaugh River, while running at a speed of 50 mi. per hr. The curve is laid with steel ties, of the Carnegie Steel Co.'s type (I-shaped cross-section). Investigation of the accident by a committee of officials of the railway [composed of H. M. Carson, Assistant to General Manager; L. R. Zollinger, Engineer of Maintenance-of-Way, and A. C. Shand, Chief Engineer] resulted in a report containing the following:

On examination of a brake beam we found that the end on the left side had been caught under the flange of the wheel, as the marks made by the flange plainly indicated, although the abrasions on the end of the beam were hardly sufficient to indicate positively that the beam came down at the time of derailment, and had dragged the entire distance. It should also be noted that an examination of the two parts of the broken brake-hanger, which was rectangular in shape, and made of one piece of ¾-in. iron, showed that one corner of it had been worn by the flange of the wheel at some previous time, although in this condition it was strong enough to withstand ordinary service.

We are unable to definitely account for the cause of the accident, but the best reason for it that we can advance is, that at the point where the derailment occurred some foreign material became wedged between the flange of the left rear tender truck wheel and the inside or low rail, which, on account of the rigidity of the steel ties and fastenings, and on account of the low temperature, the temperature being 12° below zero, produced sufficient lateral force to shear the bolts on the outside rail.

The track was torn up a distance of 1,244 ft. The outer rail was found shoved off the ends of the ties, the outer bolt fastenings having been snapped off the whole distance of 1,244 ft. Some of these bolts were found in the river, 200 ft. from the track. The inside clips of the inner rail had been badly damaged by derailed wheels, and pieces were broken out of the base of the rail at intervals. The committee then recommends as follows:

We are of the opinion, on account of the lack of positive evidence as to the cause of the derailment, and on account of the fact that the damage subsequent to the derailment was more serious than would have been the case with wooden ties, that the remaining steel ties should be removed.

It is stated that this recommendation will be carried out at once, presumably only as affecting this particular experimental section.

A SWITCH THROWN UNDER A TRAIN derailed the rear truck of a train on the Third Ave. line of the New York City elevated railway system on Feb. 26. The accident occurred at a turnout and crossing, at Chatham Square. The truck which left the track fell to the street, and the slewed car wrecked a small auxiliary platform, which also fell to the street. By great good fortune no one was injured, although the street at this point is very busy.

THE NEW TERMINAL STATION of the Delaware, Lackawanna & Western R. R. at Hoboken, N. J., was put in use on Monday morning, Feb. 25. This station, which was fully described in Vol. LVI., No. 12, p. 297 of Engineering News, replaces the old station, which was destroyed by fire Aug. 8, 1905, and is of fireproof construction throughout.

COMPULSORY BLOCK SIGNAL EQUIPMENT is recommended by the Interstate Commerce Commission in a report presented to Congress on Feb. 25. A resolution adopted at the last session of Congress directed the Commission to investigate and report on the use of and necessity for block signal systems and appliances for the automatic control of railway trains.

Summarizing its recommendations for early and immediate legislation, the Commission says:

(1) That the use of the block system should be enforced on the passenger lines of the country in general according to the provisions of a bill in substance like the one submitted to Congress by the Commission in December, 1903, except that the time to be allowed for final compliance with its compulsory features should be made three or four years from the present. (2) That with or without the passage of a law requiring the use of block signals, there should be a law authorizing an official investigation of train accidents and providing for the employment of competent men to perform the duties imposed by such an enactment. (3) That investigation by official tests of automatic appliances for the control of railway trains should be authorized in accordance with the Commission's recommendation of Jan. 3, 1907, with an appropriation of sufficient amount to conduct tests in a proper manner.

THE CONVICTION OF A TOWERMAN closes the history of the worst elevated railway wreck in the history of New York City, the derailment of an elevated train at Ninth Ave. and 53d St., on Sept. 11, 1905, an accident in which a dozen were killed. There is a turnout at this point leading from the Ninth Ave tracks into 53d St., southbound trains of the Sixth Ave. line taking the turnout while Ninth Ave. trains take the straight track. The towerman set the switch for the turnout when a Ninth Ave. train was approaching, and signaled to the train to come ahead. The train ran through the switch at a speed of about 15 mi. per hr., and was derailed on the curve; two cars fell into the street. The accident was noted in our issue of Sept. 14, 1905. The towerman has now been convicted of manslaughter in the second degree, with a recommendation for mercy.

BIDS FOR PART OF THE CATSKILL AQUEDUCT will be received by the Board of Water Supply, New York City, on March 18. This section will be 10.83 miles long, and will involve 1,058,000 cu. yds. of excavation and 211,000 cu. yds. of concrete masonry in open cut; 170,000 cu. yds. of excavation and 45,000 cu. yds. of concrete in tunnel; 340,000 bbls. of Portland cement; 125,000 lbs. of steel for reinforcing concrete, and some 800,000 cu. yds. of refill, embankment, moving top soil, etc. The time allowed for completing the contract is 45 months. Mr. J. Waldo Smith, M. Am. Soc. C. E., is Chief Engineer of the Board of Water Supply (299 Broadway, New York City).

WATER-WHEEL UNITS OF 12,000-HP. EACH, the largest thus far attempted, will be used to drive electric generators in a power transmission plant at Vallecito, on the Stanislaus River, in California. The power will be transmitted to San Francisco and will be tapped for use in the Southern Mines and in the upper San Joaquin Valley. The operating head is 1,400 ft., equivalent to a pressure of 600 lbs. per sq. in. The present equipment calls for three 6,700-KW., General Electric generators, each to be driven by a Pelton water-wheel unit of 12,000-HP. capacity. The units will each consist of two impulse wheels, each wheel overhanging the opposite end of a heavy shaft which carries the rotor of the generator in the center. The wheels proper consist of a cast-steel annealed disk center to which are attached the buckets, also of cast-steel. The buckets will be secured to the center by means of turned steel bolts hydraulically pressed into reamed holes, a novel point in water-wheel construction. The shaft will be of hollow forged nickel steel 28 ft. in length, 20 ins. in diameter at the center, where the rotor is located, and 16½ ins. at the water-wheel journals. The wheels and rotor will be designed for a press fit on the shaft at 100 tons pressure. The journals, one on each side of the generator, will be 16½ ins. in diameter and 60 ft. long. They will be of the ring oiling ball and socket type, water jacketed, and provided with an oil pressure and gravity feed lubricating system. Electric indicators and thermostats will be installed to give warning of any excessive rise in temperature. The nozzles will be of the needle deflecting type, made of cast-steel. The gate valves will be of the single-disk type made of cast-steel with phosphor bronze seats ground in place. They will be provided with roller bearings to relieve the thrust on the stems and will be actuated through gearing by means of small Pelton motors. At the switchboard will be located the main pilot control, by means of which the gates, nozzles, and needles can be controlled by the station attendant, small Pelton motors and direct-acting plungers being employed for the purpose. All pressure parts on these units are to be given a cold water test of 1,200 lbs. per sq. in. in the shops before shipment. The Stanislaus Electric Power Co. has just closed contracts for this work, which is to be supervised by the engineering firm of Sanderson & Porter, of New York. The complete hydraulic equipment will be furnished by the Pelton Water-Wheel Co., of San Francisco, Cal., and the electric apparatus by the General Electric Co., of Schenectady, N. Y.

ELECTRICAL FIRES which have occurred since Oct. 10, 1906, are noted in the quarterly fire report just issued by the Electrical Bureau of the National Board of Fire Underwriters. The details of these losses are also given because, as explained in the report, electrical fire hazards are not as generally understood as those of other methods for producing light, heat and power. Among the most interesting cases reported are the following:

A window dresser was called away from his work and left a lighted 32 c. p. lamp resting against a wax figure in the show window. The lamp did not have a wire guard. Heat from lamp set fire to figure. Loss $1,500.

Fire was started in a large apartment house by an electric iron left with "current on" resting on a table. Heat set fire to table and surrounding material. Prompt discovery prevented serious loss.

A 32 c. p. lamp was so adjusted that a celluloid shade rested upon it. The heat of the lamp ignited shade. Burning material dropped on desk beneath and damaged papers lying thereon. Small loss.

Janitor in charge of premises of a moving picture machine concern attempted to give an impromptu performance for some of his friends. He went into the machine cabinet, which was of metal, put on a reel of film, let the film hang in front of the lens, turned on current to arc lamp but did not keep the film moving. Fire started at once and the would-be showman got out immediately, but did not close the door of the cabinet. Fire spread to room. Damage $1,000.

Wires feeding window lights in a large department store were run in iron conduit. No bushing was provided on the end of conduit and the sharp edge in time cut into the insulation of the wires as they were moved a little each time the windows were washed, and formed a ground. Large loss.

In the parlor of a hotel having a direct-current isolated plant there were two arc lamps temporarily hung, and the connection to same was made by heavy cotton-covered wires hidden on top of a picture molding. Preparatory to a political meeting the decorator tacked bunting, etc., to the molding, and evidently the tacks penetrated the coverings of the wires, causing a short-circuit when current was turned on. Damage $50.

LABOR LEGISLATION recently enacted in France requires an employer to allow a workman one day of rest each week. As a result of this law, a controversy arose as to the amount a workman who has been working on a seven-day weekly basis should be paid for a six-day week's work. The Court of Cassation at Paris has decided that an agreement made between employer and employee before the passage of the new law fixed the weekly salary by contract and it should continue to hold, notwithstanding the reduction of working time, until it was dissolved or replaced by a new agreement. But, in the general case, the Court held that, although the law prohibited an employer from using a workman more than six days each week, it did not impose upon him the obligation of paying that workman for his day of rest.

A somewhat similar condition arose in this country last summer, when the President ordered that the dormant eight-hour day law should be enforced on all government contracts. In many cases the contractors were working men ten-hour days at a daily wage, and the workmen objected to the proportionate decrease in pay when the eight-hour day went into effect. In the absence of any contract or agreement other than the usual method of hiring men on large contracting work, which consists of an order to go to work at so much per day, the workmen had to submit to the reduction or leave the work.

A TEN-COUPLED LOCOMOTIVE of the 2-10-2 class for heavy coal service on the Pittsburg, Shawmut & Northern Ry. has recently been completed by the Baldwin Locomotive Works, and is No. 30,000 of the engines built by that firm. It is a simple engine with superheater, the superheating device consisting of a nest of curved tubes inside the smokebox which is 8 ft. 4 ins. long. The upper header on each side is connected to the main steam pipe, while the lower header is connected to the steam passage to the cylinder. The boiler is of the extended wagon-top type, and carries a pressure of only 160 lbs. The spring rigging is arranged in two groups, the first including the front truck and three driving axles, and the other including the other driving axles and the rear truck. The connecting rods are attached to the middle wheels, and return cranks carry the rods of the Walschaert valve gear. The leading dimensions are as follows:

Driving wheels	4 ft. 9 ins.
Wheelbase, driving	19 ft. 9 ins.
Total engine	35 ft. 11 ins.
Engine and tender	67 ft. 4½ ins.
Weight, on drivers	233,000 lbs.
Total engine	288,000 lbs.
Engine and tender	450,000 lbs.
Cylinders	28 × 32 ins.
Boiler, diameter	6 ft. 6⅜ ins.
Firebox	9 × 6½ ft.
Tubes: No., 391; diameter	2¼ ins.
Tubes, length	20 ft. 0 ins.
Heating surface, tubes	4,586 sq. ft.
Firebox	210 sq. ft.
Total	4,796 sq. ft.
Grate area	58½ sq. ft.
Water (cylindrical tank)	8,500 gals.
Coal	14 tons
Tractive effort	60,000 lbs.

THE ORLAND IRRIGATION PROJECT IN CALIFORnia has been conditionally alloted $650,000 from the U. S. Reclamation fund. The Orland project is the first unit of the greater project in the Sacramento Valley. The lands under the Orland project lie along Stony Creek, waters from which it is proposed to store for irrigation. If the project is carried through, it is expected that the grain fields of this section, which it is said have been unremunerative of late, will rapidly give place to vineyards and orchards. Irrigation on a small scale has ben practiced in this part of the Sacramento Valley for a long time. The conditions under which the allotment for the Orland project has been made are summarized as follows:

(1) That 12,000 acres of land be pledged by the owners in a form to be approved by the Department, such that the lands will be held bound to repay the cost of construction under the terms of the Reclamation Act.
(2) That satisfactory arrangements be made and agreements completed for the adjustment of water rights or for options to purchase certain properties and rights.
(3) That satisfactory arrangements be made for the purchase of the lands needed for reservoir purposes.
(4) That the owners of the lands agree to subdivide and sell their lands needed for reservoir purposes.
(5) That the owners of the lands agree to subdivide and sell their holdings in excess of 160 acres in farm units of not to exceed 40 acres.

SAILING VESSELS have always held an advantage over steam in the long voyage from English ports around Cape Horn, to San Francisco or Puget Sound ports. A consular report states that the steamship "Kalibia" has just sailed from Newcastle-on-Tyne for San Francisco with a general cargo. The distance is nearly 15,000 miles. A Newcastle daily paper says:

> She will be the first steamship that has ever been chartered from the Tyne for such a voyage. Of course, the way has been paved by the substitution of steam for sail vessels in the trade with the west coast of South America—a trade which in three or four years has been completely revolutionizd, steamers now carrying the great bulk of the coal cargoes which are shipped to Chile and Peru. If it is successful, one wonders what will become of the windjammers which have hitherto had a monopoly of the carrying trade between Europe and California. There will be little left for them to do, and the day of their extinction will be at hand.

THE RATE OF RECESSION OF NIAGARA FALLS is reported on in a recent bulletin of the U. S. Geological Survey by G. K. Gilbert. Surveys to determine the outline of the crest of the falls of Niagara were made in 1842, 1875, 1886, 1890 and 1905. The last was made specifically to furnish accurate data on the recession or wearing of the falls; it was thought that the increasing abstraction of water for power generation will soon modify the rate of erosive recession, so that data as to the *natural* rate, which is of high importance to geologists, can not be calculated from future surveys. The author deduces a mean rate of 5.3 ft. per year for the Horseshoe Fall, and a mean rate of 0.2 to 0.5 ft. for the American Fall. Besides the records of the surveys above noted, several camera-lucida sketches made in 1827 by Capt. Basil Hall, are available. These, with other data, served to show that the 1842 map is badly in error as to the American Fall, but probably correct as to the Horseshoe. A perusal of the pamphlet brings out nothing more clearly to the engineer than that the various surveys disagree to a remarkable extent. Equally remarkable is the fact that the 1905 survey, which doubtless was intended to be better than the previous ones, was made with a plane-table, giving no numerical record, but only a map plot, of the results. This survey is separately reported, in the same bulletin (Bulletin No. 306), by W. Carvel Hall. The Director of the Geological Survey should be addressed for copies of the pamphlet.

MOTOR-CAR OPERATION on the Arad & Csanad Ry., in central Hungary, is described as very successful. Mr. A. Heller, writing on the matter in the "Zeitschrift des Vereines Deutscher Ingenieure" of Nov. 3, states that this railway, with 243 mi. standard-gage line and 109 mi. narrow-gage (30-in.) line, now owns 37 standard-gage motor cars, 8 narrow-gage motor cars and 3 narrow-gage freight locomotives. Of these by far the larger number (33) are of the combination gasoline-electric kind, 14 are steam cars, and only one is a pure gasoline car; 13 of the total number are rated at 70 HP., the others 30 to 40 HP. each. Most of them are operated with one to four small trailers. These trains make speeds of 18 to 35 mi. per hr., and can run 18 to 150 mi. without stopping for fuel. The standard-gage motor cars have made annual mileage from 55,000 to 230,000 miles, and show total operating costs (maintenance included) of 2.06 cts. to 2.80 cts. per train-mile, the smaller figure being applicable to the steam cars (charcoal-fired).

THE RAILWAY DEVELOPMENT OF CANADA has increased during the past year to such an extent that it is thought the Canadian Government will either suspend the Alien Labor Act and allow railway companies and contractors to bring in new men during the coming year, or bring them in itself and hire them out to the employers of labor. During the past year it is estimated that 3,314 miles of new road were under construction, and that $62,000,000 have been spent upon the work and equipment. The Canadian Pacific has added to its system about 750 miles of new track at a cost of $15,000,000, besides 100 miles of double-tracking between Fort William and Winnipeg. The Canadian Northern has 660 miles of new road under construction, the cost of which will be over $10,000,000. The Grand Trunk Pacific has about 990 miles under construction in the West. This is made up of 790 miles west of Winnipeg and 200 miles from Fort William to Superior Junction. The expenditure during the year on this work will reach $6,000,000. The Government is also building 245 miles from Winnipeg to Lake Superior Junction and 150 miles from Quebec to La Luque. The Temiskaming and Northern Ontario Railway has also built track costing $2,000,000. Besides this vast mileage costing in the aggregate about $44,000,000, the sum of $18,000,000 has been expended during the year in equipment. This year the railway development promises to be still more extensive. The Grand Trunk Pacific alone will require 15,000 men in order to carry forward their summer's operations. Besides many improvements planned for the Intercolonial Ry., the Government will push forward the building of the National Transcontinental Ry. About 425 miles of this line are now under construction and it is expected that by next spring the Government will have in all 879 miles of this line in progress. A conservative estimate is that 3,000 miles of railway will be under construction during the summer and fall of the present year, and that between 40,000 and 50,000 men will be required for the work.

PERSONALS.

Mr. Thomas F. Whittelsey has resigned as General Manager of the Mobile, Jackson & Kansas City R. R.

Mr. Joseph Wanbeck has been appointed Resident Engineer of the Ann Arbor & Detroit R. R. and the Toledo & Ironton R. R.

Mr. O. E. Selby has been appointed Engineer of Bridges and Structures of the Cleveland, Cincinnati, Chicago & St. Louis Ry.

Mr. F. J. Hahn has been appointed Superintendent of Transportation of the Cotton Belt & Northern Ry., to succeed the late A. B. Liggett.

Mr. L. E. Haislip has been appointed Assistant Division Engineer of the Pittsburg Division of the Baltimore & Ohio R. R., to succeed Mr. E. D. Jackson, promoted.

Mr. J. J. Flynn, General Foreman of the Louisville & Nashville R. R. shops at Mobile, Ala., has been promoted to be Master Mechanic of the company's shops at Nashville, Tenn.

Mr. A. R. Oster, Superintendent of the Eastern Division of the El Paso & Southwestern R. R., has resigned to become General Manager of the Sonora Ry., a branch of the Southern Pacific.

Mr. W. T. Caldwell, Inspector of Terminals of the Queen & Crescent Route, has been promoted to be Superintendent of the Chattanooga Division, and his former office abolished.

Mr. R. Marpole, General Superintendent of the Pacific Division of the Canadian Pacific Ry., has been appointed General Executive Assistant, with office at Vancouver, B. C.

Mr. Myron B. Vorce, Inspector of Buildings at Cleveland, Ohio, has resigned to become President of the Vorce Engineering Co. This is a new company lately organized in that city.

Mr. A. H. Payson, President of the Spring Valley Water Co., San Francisco, Cal., has been elected President of the Northwestern Pacific R. R., to succeed Mr. E. E. Calvin, resigned.

Mr. J. C. O'Dell, formerly Division Superintendent of the Central of Georgia Ry., has been elected General Manager of the Georgia, Florida & Alabama Ry., to succeed Mr. W. B. Denham.

Mr. James Agler has been elected General Manager of the Northwestern Pacific Ry. Mr. B. F. Porter has been made Assistant General Manager and Mr. F. K. Zook, Engineer in charge of Maintenance of Way.

Mr. W. Leon Pepperman, Assistant Chief of the Office of Administration of Canal Affairs, at Washington, D. C., has resigned and has accepted a position with the Interborough-Metropolitan Co., of New York City, under Mr. Theodore P. Shonts, the newly elected President, who will retire from the Canal Commission March 4. A sketch of Mr. Pepperman was given in our issue of July 20, 1905.

Mr. H. M. Stone has been appointed Engineer of the Northern District of the Chicago, Rock Island & Pacific Ry., with headquarters at Cedar Rapids, Iowa, to succeed Mr. Garrett Davis, transferred. Mr. J. G. Bloon, Engineer of Maintenance, at Topeka, Kan., has been made Engineer of the Southwestern District, with office at Topeka. Mr. C. M. Case has been appointed Chief Engineer at Fort Worth, Tex., to succeed Mr. J. S. Peter, resigned.

Obituary.

Nicholas White, a contractor of Medford, Mass., died at his home in that city, Feb. 24, aged 85 years. He was born at Galway, Ireland, and came to Boston, Mass., nineteen years later.

Horatio Seymour, M. Am. Soc. C. E., at one time State Engineer of New York, died at his home in Utica, N. Y., Feb. 21, aged 63 years. He was born at Utica and graduated from Yale University in 1867.

James N. Weaver, for 20 years Master Mechanic of the Lehigh Valley R. R. shops at Sayre, Pa., died at his home in that city, Feb. 13. He retired from the railroad service in 1898 and since then had been Postmaster at Sayre.

William C. McMillan, President of the Detroit & Cleveland Navigation Co. and the Detroit & Buffalo Steamship Co., died at his home in Detroit, Feb. 21, of pneumonia, aged 46 years. He was a graduate of Yale University.

George H. Evans, M. Am. Soc. M. E., a civil and mining engineer of San Francisco, Cal., died at Berkeley, Cal., Feb. 4, after undergoing an operation. He was born at Hull, England, 41 years ago. He made a specialty of placer mining and was the inventor of Evans' hydraulic elevator. He was a member of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the Franklin Institute, the North of England Institute of Mining and Mechanical Engineers, and the Technical Society of the Pacific Coast.

Frank J. Hearne, M. Am. Inst. M. E., President of the Colorado Fuel & Iron Co., died at Denver, Colo., Feb. 25. He was born at Cambridge, Md., Sept. 21, 1846, and graduated from Rensselaer Polytechnic Institute in 1867. He at once became Chief Engineer of the Hannibal & St. Joseph R. R., but in 1872 organized an iron company at Wheeling, W. Va. Two years later his company was incorporated into the Riverside Iron Works and he became Assistant General Manager, later being advanced to General Manager. In 1899 the Riverside Iron Works were purchased by the National Tube Co. and Mr. Hearne was elected First Vice-President. The following year he was elected President, with headquarters at Pittsburg, Pa. He was elected President of the Colorado Fuel & Iron Co. in September, 1903.

Charles Davis, M. Am. Soc. C. E., County Engineer of Allegheny County, Pa., died at his home in Edgeworth, Pa., Feb. 21, of pleurisy. He was born at Bridgetown, Pa., July 11, 1837, and entered Jefferson College in 1858. He left college in his junior year and enlisted in the army, serving through the Civil War. After his discharge from the army he entered the Engineering Corps, later accepting a position on the surveying corps of the Western Pennsylvania R. R. In 1867 he was elected City Engineer of Allegheny, which position he held for eight years. He was employed in 1878 in making preliminary surveys for the Pittsburg & Lake Erie R. R., and in 1880 became Superintending Engineer in the erection of the Homestead plant of the Pittsburg Bessemer Steel Co. He retained this position until 1881, when he was elected County Engineer of Allegheny County. Besides being a member of the American Society of Civil Engineers, he was a charter member and Past President of the Engineers' Society of Western Pennsylvania.

ENGINEERING SOCIETIES.

COMING MEETINGS.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.
March 19-21. Annual Meeting at Chicago, Ill. Secy., L. C. Fritch, 1562 Monadnock Block, Chicago, Ill.
IOWA ELECTRICAL ASSOCIATION.
April 18-19. Annual Meeting at Clinton, Iowa. Secy., L. B. Spinney, Iowa State College, Ames, Iowa.
THE AMERICAN RAILWAY ASSOCIATION.
April 24. Annual Meeting at Chicago. Secy., W. F. Allen, 24 Park Pl., New York City.

THE RAILWAY SIGNAL ASSOCIATION.—A meeting of the association will be held at Chicago, Ill., March 18. Discussion on General Specifications for Electric Interlocking; Installation and Maintenance of Storage Batteries; Signal Lamps—Design of, etc.; and Special Committee's report on Interlocking and Block Signals will be held. Headquarters will be at the Great Northern Hotel.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS held its regular meeting on Feb. 20th, Mr. G. W. Tillson in the chair. Two papers were read, as follows: "Rainfall and Run Off in Storm Water Sewers," by Mr. C. E. Gregory, and "The Design of the New Croton Dam," by Mr. Edward Wegman. On account of their number and length, discussions on the former paper were not read, but Mr. Charles S. Gowen and Mr. Wegman entered into a lengthy discussion of certain points in the design of the New Croton Dam. The secretary announced that some 50 votes additional were needed to bring the ballot on the advisability of appointing a committee to report on Engineering Education up to the number required for a legal ballot under the constitution. All members who have not voted are requested to do so.